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Fiber Optic Transmission for Enhanced Network Services

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Fiber-Optic Transmission for Enhanced Network Services

Recent Trends in Fiber-Optic Transmission Technologies for Information and Communication Network

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Abstract

Fiber-optic-transmission technologies have been developing considerably to satisfy demand for large-capacity digital transmission in public telecommunication networks. Gigabit-per-second (Gbit/s) transmission systems have already been put into practical use for trunk line networks, and next-generation 10-Gbit/s systems are being intensively developed. On the other hand, various information services including voice, data and moving images are becoming indispensable to human activities in step with the recent development of the information society. Therefore, the broadband Integrated Services Digital Network (ISDN) and the high-speed multimedia Local Area Network (LAN) are being intensively developed. Fiber-optic transmission technologies are expected to be deployed in various fields, from present trunk lines to subscriber loops and also in local-area high-speed information networks. Hitachi is actively contributing to the evolution of the information society by promoting development of optical transmission technologies and products.

Introduction

Fiber-optic transmission technologies utilizing optical fiber transmission lines support high-speed/large-capacity and long-distance transmission and have been developing considerably to satisfy demands in large-capacity digital transmission in public telecommunication networks. At first, optical transmission technology with speeds of several tens of Mbit/s using multimode optical fibers as transmission lines was developed in the 1970s. In the 1980s, high-speed transmission technologies having transmission speeds from several 100 Mbit/s to Gbit/s were developed based on the development of single-mode optical fiber technology.

The above technologies have been utilized to realize large-capacity digital transmission mainly in trunk lines of public telecommunication networks. Recently, however, various information services including voice, data and moving images have become indispensable to human activities. Therefore, the broadband ISDN in public transmission networks and the high-speed multimedia LAN in in-house information networks are being intensively developed. Fiber-optic transmission technologies, as key technologies to realize a highly-developed information society, are expected to be deployed in various fields, from present trunk lines to subscriber loops in public telecommunication networks and also in local-area high-speed information networks, as shown in Fig. 1.

Here, we describe new technological trends in optical transmission toward high-speed/large-capacity transmission and the impact on telecommunication and information networks.

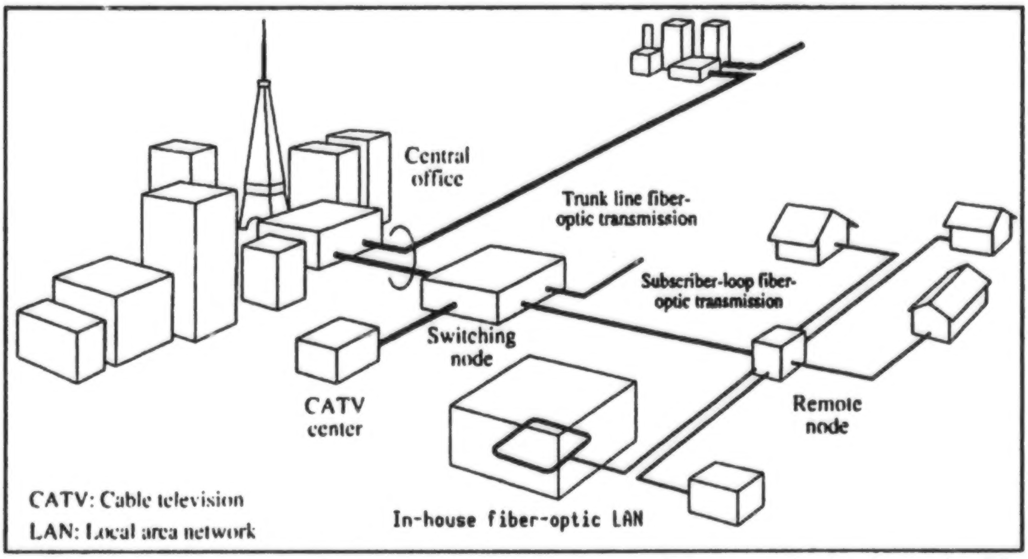

Figure 1. Fiber-Optic Transmission Technologies in Information and Telecommunication Networks. Fiber-optic transmission technologies developed mainly for trunk line transmission networks are being deployed in various high-speed/large-capacity networks from trunk lines to subscriber loops in public telecommunication networks and also in in-house information networks.

Technological Trends

Optical transmission technologies first commercialized in the early 1980s have been developing considerably. The transmission speed has increased an order of magnitude in the past 10 years, as shown in Fig. 2. 100-Mbit/s optical transmission systems in the early 1980s were put into practical use using multimode optical fibers and 0.8-μm wavelength lasers. It was, however, clarified that long-distance transmission of high-speed optical signals is difficult through multimode fibers due to mode dispersion and that loss of optical fibers is lower in the wavelength range above 1 μm. High-speed transmission systems were, therefore, developed using single-mode optical fibers and 1.3-μm wavelength lasers. In the mid-1980s, the fiber loss was further lowered in the 1.55-μm wavelength range and distributed feedback (DFB) lasers, which have superior single mode characteristics, were developed. Then, in the late 1980s, 1-?-Gbit/s high-speed transmission systems utilizing these technologies were put into practical use. In parallel with the development of high-speed technologies, international standards for transmission systems were actively being discussed and the synchronous digital hierarchy (SDH) was standardized by ITU-T (Footnote 1: ITU-T (International Telecommunications Union-Telecommunications Standardization Sector), formerly CCITT (international Telegraph and Telephone Consultative Committee)) in 1988. Based on this SDH, 2.4-Gbit/s optical transmission systems were put into practical use in 1990 and are now the highest-speed commercialized optical transmission systems.

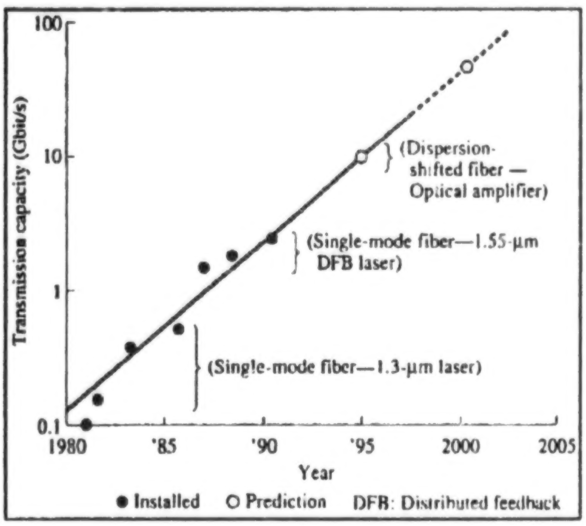

Figure 2. Trend of Fiber-Optic Transmission Systems in Trunk Line Transmission Networks. Transmission speed has been increased an order of magnitude in the past 10 years based on the progress of fiber-optic technologies.

In the future, 10-Gbit/s systems in the mid-1990s and 40-Gbit/s systems in the year 2000 are expected to be put into practical use, based on the prediction shown in Fig. 2. The development of new transmission technologies for these systems has progressed. The basic configuration of optical transmission (a), a conventional method of optical signal generation and detection (b), and a new method being developed for high-speed transmission (c) are shown in Fig. 3. In the conventional method, optical signals are generated by direct modulation of a laser and detected and converted to electronic signals by a detector, such as an avalanche photodiode (APD). However, since signal distortion, due to fiber dispersion and reduction of receiver sensitivity, must be overcome to realize higher transmission speeds, new methods were developed: 1) an external modulation method where the optical output from a laser is modulated by an optical modulator and 2) an optically-amplified signal detection method where the optical signal amplified by an optical amplifier is detected by a detector. Further, dispersion-shifted fibers were developed, which have zero dispersion in the wavelength range of 1.55 μm.

Among the new technologies, progress in optical amplifier technology has been remarkable. The optical amplifier can be used not only for improving receiver sensitivity, but also for enlarging transmitter optical output, and it can be used as an optical repeater. Therefore, this device is expected to reduce restrictions in transmission system design. The optical fiber amplifier uses the principle that optical signals of 1.55-μm wavelength are amplified through an erbium-doped fiber excited by a laser light of 0.98-μm or 1.48-μm wavelength. An example of optical fiber amplifiers is shown in Fig. 4. In this case the erbium-doped fiber is excited from both ends for use as an optical repeater. Front end excitation is usually used for receivers and back excitation for transmitters. Very recently, optical fiber amplifiers are becoming commercialized for long-distance transmission.

Using the technologies mentioned above, 10 Gbit/s optical transmission over more than 300 km was experimentally confirmed utilizing optical amplifier repeaters and is now being intensively developed for practical use. To realize larger capacity transmission, technologies for optically multiplexed signal transmission is important, as well as higher-speed signal transmission technologies. There is a possibility that 10-20-Gbit/s transmission will be realized based upon the new technologies mentioned above. It is, however, predicted that the limitation of higher-speed transmission would be several tens of Gbit/s, limited by the performance of optical and electronic devices and also by fiber dispersion. It is, therefore, necessary to combine high-speed technologies and optical multiplexing technologies to realize capacities of several tens of Gbit/s to Tbit/s. The optical-frequency multiplexed transmission method has attracted much attention for large-capacity transmission, by which multiple optical signals having different wavelengths are independently modulated and

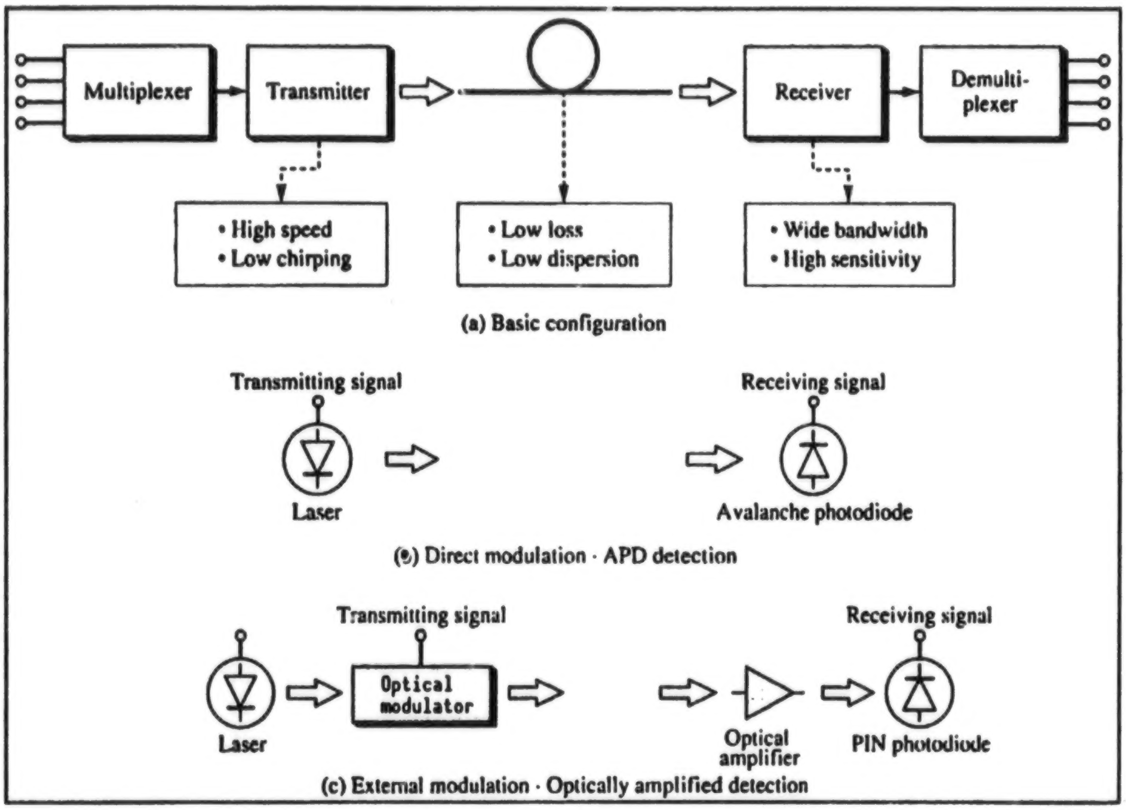

Figure 3. Basic Configuration and Progress of Fiber-Optic Transmission. Technologies of external modulation and optical amplification have been developed, which enable 10-Gbit/s transmission speeds.

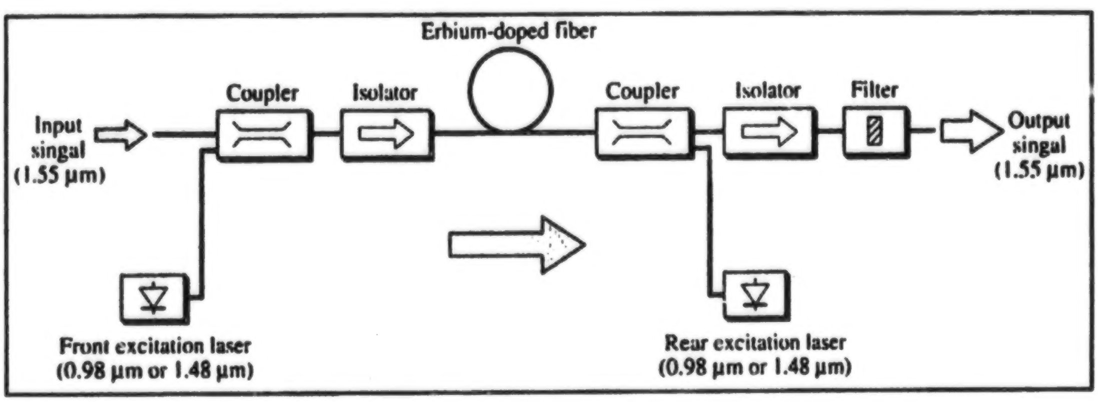

Figure 4. Configuration of an Optical Fiber Amplifier. A 1.55-μm wavelength optical signal is amplified by exciting an erbium-doped fiber by 0.98- or 1.48-μm wavelength laser light.

optically multiplexed into a single optical fiber. Approaches toward realization of Tbit/s transmission speeds are shown in Fig. 5. 100-Gbit/s transmission can be realized, for instance, by multiplexing 10 channels of 10-Gbit/s optical signals and further 1-Tbit/s transmission by multiplexing 100 channels.

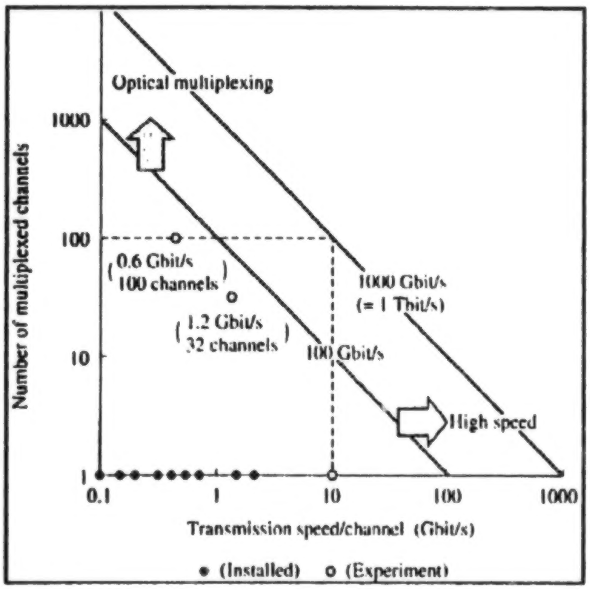

Figure 5. Approaches to Tbit/s Fiber-Optic Transmission Speeds. Aiming at Tbit/s transmission speeds, optical multiplexing technologies are being developed, as well as other high-speed technologies.

Research and Development of Optical Transmission Technologies

As mentioned above, high-speed/large-capacity transmission technologies are being intensively studied. Hitachi is also actively involved in research and development of wide-range fiber-optic transmission technologies. Here, two topics are introduced among the new technologies being developed at Hitachi.

Optical Modulators

For high-speed transmission, external optical modulators have been intensively studied as mentioned in the previous section. In the conventional direct modulation method where the semiconductor laser is directly modulated by electronic signals, wavelength chirping in transmission signals is substantially large. This causes distortion of the optical pulse shape, due to the fact that the propagation speed of the optical pulses is different at different wavelengths because of refractive-index dispersion in the optical fiber. This distortion becomes more significant as transmission speed and transmission distance increase. On the other hand, by using an external modulator, wavelength chirping can be drastically reduced. The optical modulator has long been studied using $LiNbO_3$ materials. Recently, however, InP semiconductor material has attracted much attention, because it enables integration with other semiconductor devices and has the potential for high reliability.

Two types of semiconductor optical modulators are being studied at Hitachi. One is a Mach-Zehnder type modulator. In this device, the electro-refractive effect, where the refractive index of the semiconductor material changes with the applied voltage, is used to modulate input laser light. This device, therefore, enables essentially zero wavelength chirping, which is necessary to very long distance transmission. An InGaAs/InAlAs Multiple Quantum Well (MQW) structure is introduced for waveguides to reduce the driving voltage below 4.0V. Insertion loss of the modulator is about 10 dB, which can be compensated for by an optical amplifier. A small-signal frequency bandwidth above 12 GHz was achieved and 10-Gbit/s transmission was successfully demonstrated.

The other is an electroabsorption (EA) type modulator. In this device, the EA effect, where the absorption of input light is changed by the applied voltage, is used. When the absorption is changed, the refractive index is inevitably changed. This device, therefore, causes a small amount of wavelength chirping. Advantages of this device, however, are a small driving voltage (below 2.0V) and the ability to be integrated into semiconductor lasers. So far, two-step epitaxy of the semiconductor material has been employed to fabricate integrated devices, since the modulator and laser each have a different structure. This process, however, causes degradation of device characteristics, due to the difficulty in connecting devices grown with the different step epitaxy. A new technology for fabricating the integrated device by one-step epitaxy was developed at Hitachi. By employing this technology, stable device characteristics and low insertion loss below 2 dB were realized. 10-Gbit/s modulation at a pulse voltage of 1.5V was confirmed.

Coherent Frequency Division Multiplexed (FDM) Transmission Systems

Optically multiplexed transmission technologies look promising for large-capacity transmission systems, as mentioned in the previous section. There are several schemes to realize optical multiplexing. One is multiplexing intensity-modulated different-wavelength optical signals, which is usually called wavelength division multiplexing (WDM). One of the other schemes is multiplexing optical-frequency-modulated different-wavelength signals, which are detected utilizing coherent technology at the receiver. In this scheme, wavelength spacing between signals can be minimized to below 0.1 nm corresponding to a frequency of 10 GHz, because the receiver has high wavelength selectivity. This scheme is, therefore, usually called frequency division multiplexing (FDM). The configuration of a prototype FDM transmission system developed at Hitachi is shown in Fig. 6. In this system, multiple frequency-modulated signals are

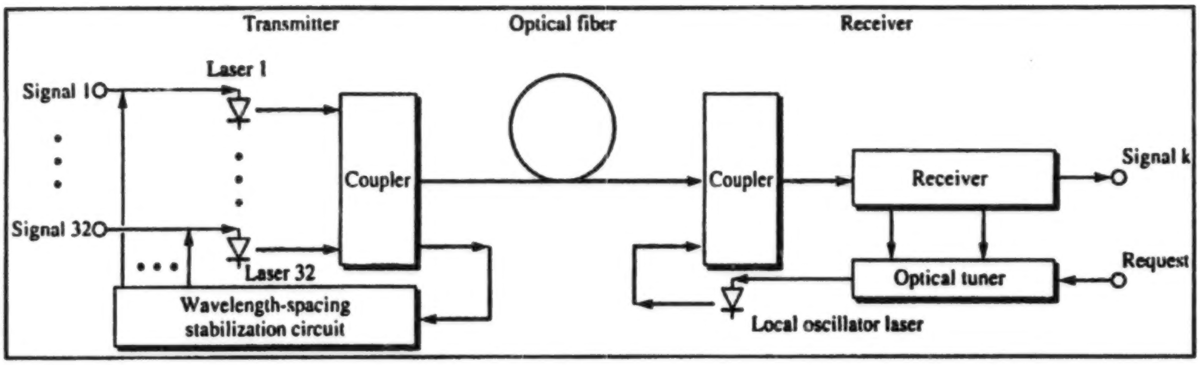

Figure 6. Configuration of a Prototype Coherent FDM Transmission System. Multiple different-wavelength optical signals corresponding to a 40-Gbit/s speed are multiplexed and transmitted through a 121-km length optical fiber and detected by a heterodyne receiver.

coupled into a single-mode fiber by an optical coupler and are transmitted through the optical fiber. One of the transmitted signals is detected by a heterodyne receiver, where the signal is mixed with laser light from a local oscillator laser whose wavelength is tuned to that of the transmitted signal. By this heterodyne method, the receiver itself has superior wavelength selectivity. In the system shown in Fig. 6, the transmitter has 32 channel lasers and each laser is frequency modulated at 1.244 Gbit/s. Total transmission capacity is, therefore, 40 Gbit/s. Wavelength (optical-frequency) spacing is 0.08 nm (10 GHz) in the wavelength range of 1.55 μm. 40 Gbit/s transmission at a distance of 121 km was confirmed. This prototype system demonstrates the possibility of large-capacity transmission using coherent technology.

Impact on Telecommunication Networks

Broadband ISDN is being extensively studied for public telecommunication networks; it integrates various information services such as voice, computer data and moving images towards realization of an information society in the 21st century. A prediction is that total information volume transmitted through telecommunication networks will be 20 times in 2005 and 130 times in 2015 compared with the present volume. It means that large-capacity transmission, for instance, Tbit/s on trunk lines, Gbit/s on business subscriber loops and 100 Mbit/s on general subscriber loops will be necessary. In the U.S., a national project has started on development of nationwide large-capacity telecommunication networks with Gbit/s range interfaces.

To realize these high-speed telecommunication networks, fiber-optic transmission technologies, such as optical amplifiers and optical multiplexers, play important roles. Examples of system architectures for trunk lines and subscriber loops are shown in Fig. 7. In trunk lines, larger capacity longer-distance transmission is important, and key technologies are optical frequency multiplexing and optical repeaters, as shown in Fig. 7 (a). In subscriber loops, multi-channel moving images are a major service and the key technology is distribution of information. An example shown in Fig. 7 (b) uses multiple optical signals having different optical frequencies allotted to different picture information. Those signals multiplexed and transmitted through an optical fiber are distributed by optical amplifiers and optical branches to a large number of subscribers. Although those technologies should be further studied, they are expected to be key technologies for realizing future high-speed telecommunication networks.

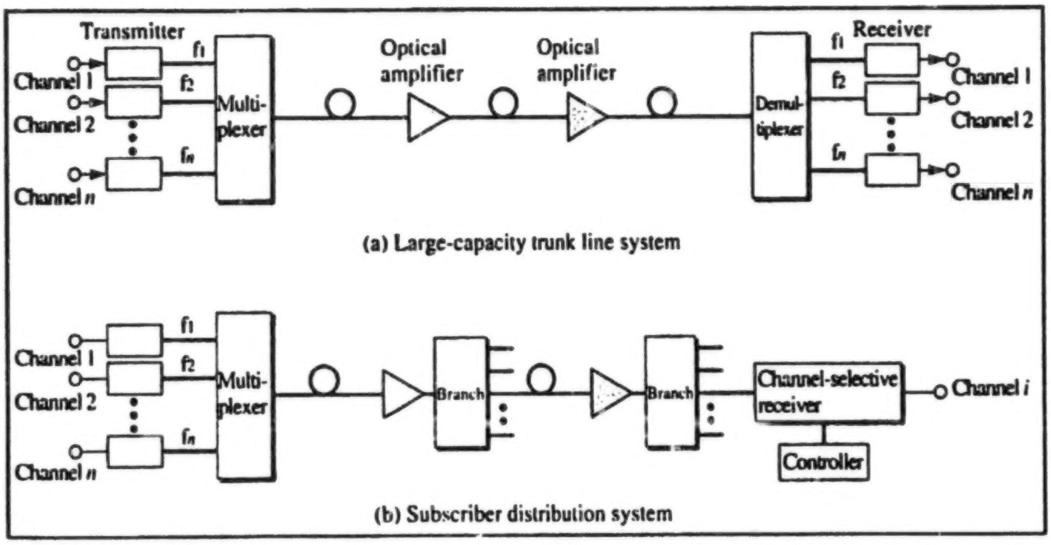

Figure 7. Progress of Trunk Lines and Subscriber Loops Through Optical Amplification and Optical Multiplexing Technologies. Large-capacity long-distance transmissions in trunk lines and multi-channel distribution systems in subscriber loops can be realized by utilizing optical amplification and multiplexing technologies.

Impact on Information Networks

For in-house information networks such as LANs in offices and factories, transmission speeds have increased almost an order of magnitude from 10-Mbit/s Ethernet (Footnote: Ethernet is a registered trademark of XEROX Corporation.) to 100-Mbit/s fiber distributed data interface (FDDI), as shown in Fig. 8. Further FDDI follow-on LAN (FFOL), high performance parallel interface (HIPPI) for high-speed computers and also Gbit/s LANs, including those technologies, are being intensively studied, especially in the U.S., towards commercialization in the late 1990s.

The Gbit/s LAN shown in Fig. 9 connects computer mainframes, storage systems and workstations at speeds above 1 Gbit/s and is also connected to high-speed public telecommunication networks to build up a wide area network (WAN). This network enables multimedia information processing, including moving images information and also high-volume diverse data processing. The fundamental fiber-optic transmission technologies for those networks have been already developed for public telecommunication networks. They should, however, be optimized for implementation in LAN environments and made more economical.

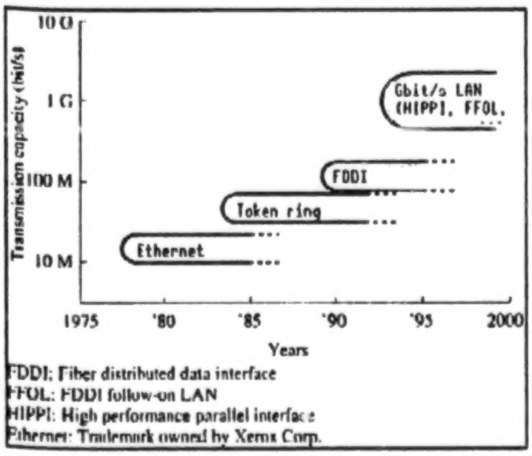

Figure 8. Trend in High-Speed LAN Technologies. Transmission speed has increased an order of magnitude in the past 10 years in in-house information networks. Gigabit/per second LANs are expected to be put into practical use in the late 1990s.

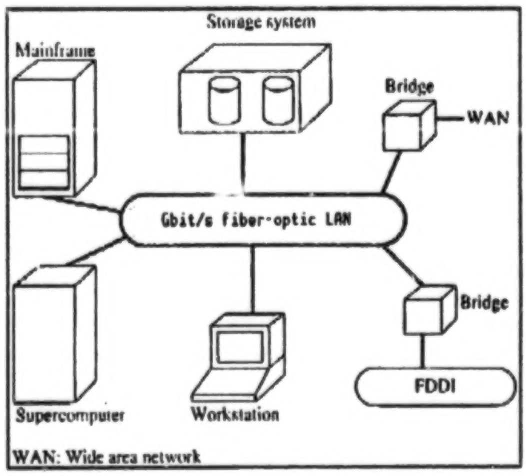

Figure 9. Gigabit-Per-Second Fiber-Optic LAN. Gigabit-per-second LANs will be utilized for multimedia (including moving images), information processing and large-volume diverse data processing.

Conclusion

Fiber-optic transmission technologies and their impact on telecommunication and information networks were described.

Optical transmission technologies have developed remarkably in the past 10 years to satisfy demand in large capacity digital transmission in public transmission networks. Gigabit-per-second range systems have already been put into practical use in trunk lines, and next generation 10-Gbit/s systems and fundamental technologies toward future Tbit/s systems have substantially progressed. Fiber-optic transmission technologies are expected to be deployed in various high-speed networks, not only in trunk lines, but also in subscriber loops in public telecommunication networks and also in in-house information networks.

Hitachi is actively involved in research and development of wide-range fiber-optic transmission technologies, such as optical and electronic semiconductor devices, optical transmitters and receivers, and also full-range transmission systems. Hitachi is contributing to the development of an information society by implementing these technologies in practical applications.

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Asynchronous Transfer Mode Network for Broadband ISDN

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Abstract

Broadband Integrated Services Digital Network (B-ISDN), based on asynchronous transfer mode (ATM) technology, is being actively studied worldwide. ATM networks can handle various types of services, such as high-speed data and video signals. Non-hierarchical multiplexing is another advantage of deploying ATM technology into the network. This paper presents newly developed ATM transport equipment and the related technologies for the ATM network. First, the key hardware technologies, such as sophisticated VLSI and optical transmission modules, are described. Next, a large capacity ATM switch architecture and an operation administration and maintenance (OA&M) junction are presented. Finally, newly developed prototype ATM transport equipment using these technologies is presented.

Introduction

Recently, high-speed communication services have become necessary for LAN interconnections and multimedia communication. Furthermore, video communication may become a major part of the traffic load in the future.

B-ISDN is a next-generation communication network that meets these high speed and multi-service requirements. B-ISDN, as illustrated in Fig. 1, can handle various types of communication applications, using asynchronous transfer mode (ATM) techniques. In the ATM network, information is transferred in 53-byte cells; hence various types of services are handled in the same manner, irrespective of their information bit rates and their characteristics. ATM transport equipment can multiplex and connect the services simply by handling the cells because of the uniform cell length. Therefore, the networks are flexible for providing new types of services, and economical because of the simple node function. The ATM network consists of digital paths called virtual paths (VPs) and digital channels called virtual channels (VCs). Fig. 2 shows this layer structure and transport equipment function. ATM transport equipment provides virtual path connection to leased line users and ATM switching systems.[1]

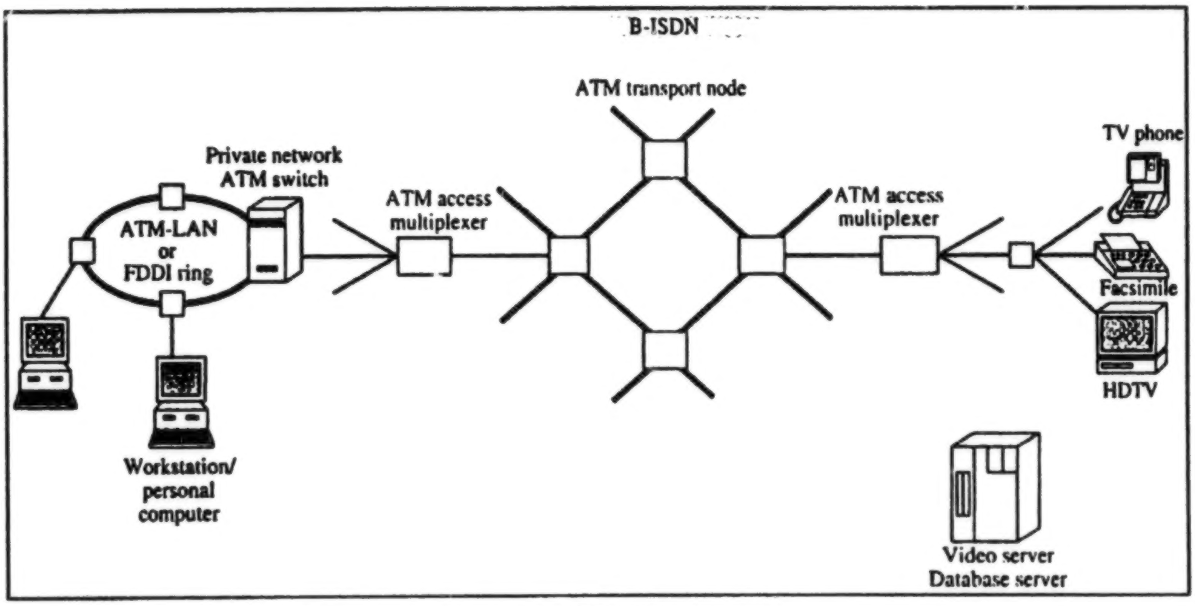

Figure 1. B-ISDN Architecture

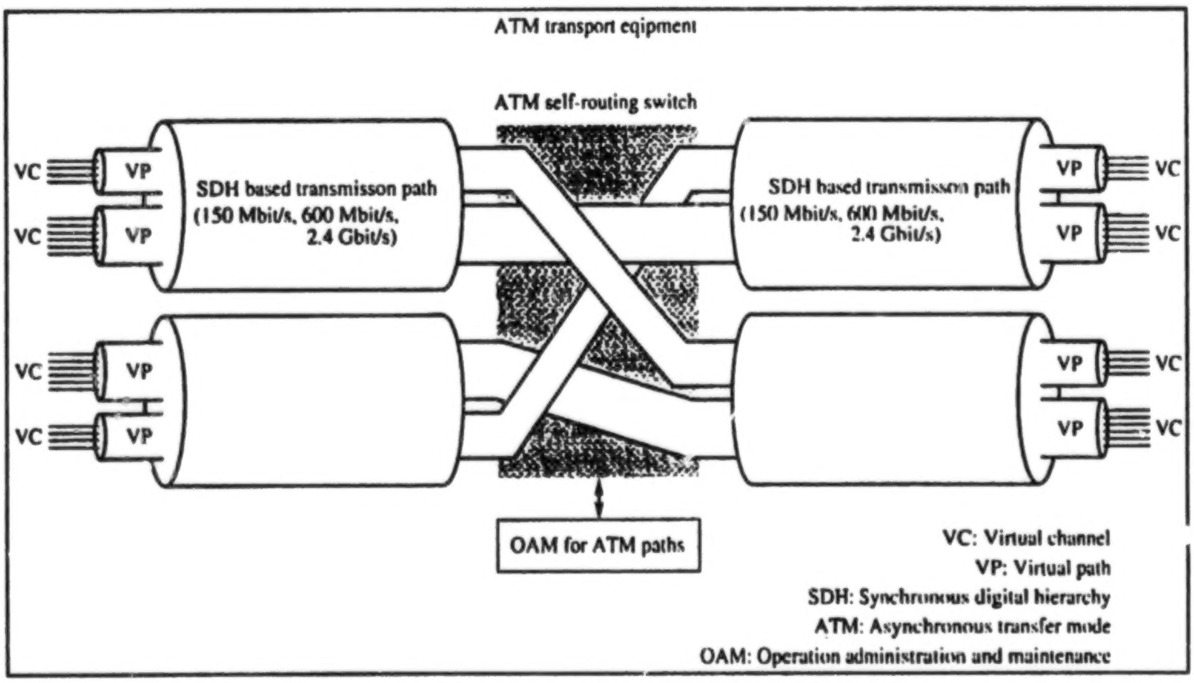

Figure 2. ATM Layer Structure and Transport Equipment Functions

This paper describes Hitachi's activity in developing ATM transport equipment and the related technologies for the ATM network. First, the key hardware technologies, such as sophisticated VLSI and optical transmission modules are described. Next, a large capacity ATM switch architecture and an operation administration and maintenance (OA&M) function are presented. Lastly, a newly developed prototype ATM access multiplexer (shown in Fig. 1) is presented.

ATM Equipment Function and Technologies

Transmission Line Interface

In the ATM network, ATM cells are transferred by STM-1 (150 Mbit/s), STM-4 (600 Mbit/s), or STM-16 (2.4 Gbit/s) SDH frames, as standardized by ITU (International Telecommunications Union).[2] Specifications of the line interfaces are shown in Table 1. Optical transmission modules and VLSIs for transmission convergence sub-layer termination (standardized processing for SDH frames and ATM cells) were developed to realize compact interface cards.

Table 1. Specifications of Line Interfaces

Interface	STM-1 (UNI)	STM-1 (Intra-office)	STM-1 (Inter-office)		STM-4 (Intra-office)	STM-4 (Inter office)		STM-16 (Inter-office)	
			≤40 km	≤80 km		≤40 km	≤80 km	≤40 km	≤80 km
Bit rate	155.52 Mbit/s				622.08 Mbit/s			2488.32 Mbit/s	
SDH frame structure	STM-1/AU-4 (ITU-G, 709, I.432)				STM-4/AU-4-4c (ITU-G, 709, I.432)			STM-16/AU-4-16c (ITU-G, 709)	
ATM cell structure	53 byte/cell (ITU-I, 361)								
Wavelength	1.31 µm	1.31 µm	1.31 µm	1.55 µm	1.31 µm	1.31 µm	1.55 µm	1.31 µm	1.55 µm
Type of fiber	SMF	SMF	SMF	DSF	SMF	SMF	DSF	SMF	DSF

SMF: Single mode fiber

DSF: Dispersion shifted fiber

ITU: International Telecommunications Union

STM: Synchronous transport module

The STM-1 and STM-4 optical transmission modules were fabricated by advanced custom ICs using 2-µm and 1-µm Si-bipolar processes, respectively. ICs for the STM-16 interface module were developed using a 0.8-µm GaAs-MESFET process. Module volumes of STM-1 (intra-office), STM-4 (intra-office), and STM-16 (inter-office) are 10 cc, 42 cc, and 355 cc, respectively.[3]

VLSIs for transmission convergence sub-layer termination are fabricated using, mainly, a 0.8-µm CMOS VLSI with 100 kilogates per chip. These VLSIs allow a compact physical integration of complex functions, including ATM cell processing. For instance, STM-4 line interface functions (shown in Fig. 3) are offered on a single card.

Architecture of a Large Capacity ATM Switch

In B-ISDN, service information bit rates reach hundreds of Mbit/s. Therefore, the ATM switch fabric in cross-connect nodes should have a very large throughput. Hitachi developed VLSIs for an ATM switch with a throughput of 10 Gbit/s (expandable up to 20 Gbit/s).

This switch fabric applies parallel processing for the routing control and bit slicing. Fig. 4 shows a 2.4-Gbit/s 8 x 8 (throughput of 20 Gbit/s) parallel processing switch configuration. Incoming cells are divided into 16 portions and each portion is given a routing tag and distributed to switch LSIs. Each switch LSI with an independent routing control function treats the 1/16 cell according to the routing tag attached. Since this technique eliminates the need for high speed control signals between switch LSIs, a large capacity switch is easily achieved using bit slicing.

Low speed (150 Mbit/s, 600 Mbit/s) interfaces can also be linked to this switch via demultiplexer switches and multiplexers. Shared buffer type switches[4] are adopted as these demultiplexer switches to realize bursty traffic tolerance. The specifications of these switch LSIs are shown in Tables 2 and 3. Several types of ATM switches can be constructed by the appropriate combination of these LSIs.

Table 2. Specifications of 2.4-Gbit/s Parallel Processing Switch LSI

Item		Specifications
Input-output links	32 switch LSI configuration 16 switch LSI configuration	2.4 Gbit/s 8 x 8 (throughput of 20 Gbit/s) 2.4 Gbit/s 4 x 4 (throughput of 10 Gbit/s)
Path connection		1:1 or 1:n
Buffer type		Output buffer
Buffer size		256 cell/output port
Technology		0.8-µm CMOS

Table 3. Specifications of Shared Buffer Switch LSI

Item		Specifications
Input-output links	8 buffer memory LSI configuration 4 buffer-memory LSI configuration	150 Mbit/s 32 x 32 (throughput of 4.8 Gbit/s) 150 Mbit/s 16 x 16 (throughput of 2.4 Gbit/s)
Path connection		1:1 or 1:n
Buffer type		Shared buffer
Buffer size	8-buffer-memory LSI configuration 4 buffer-memory LSI configuration	4096 cells/switch 2048 cells/switch
Technology		0.8-µm CMOS

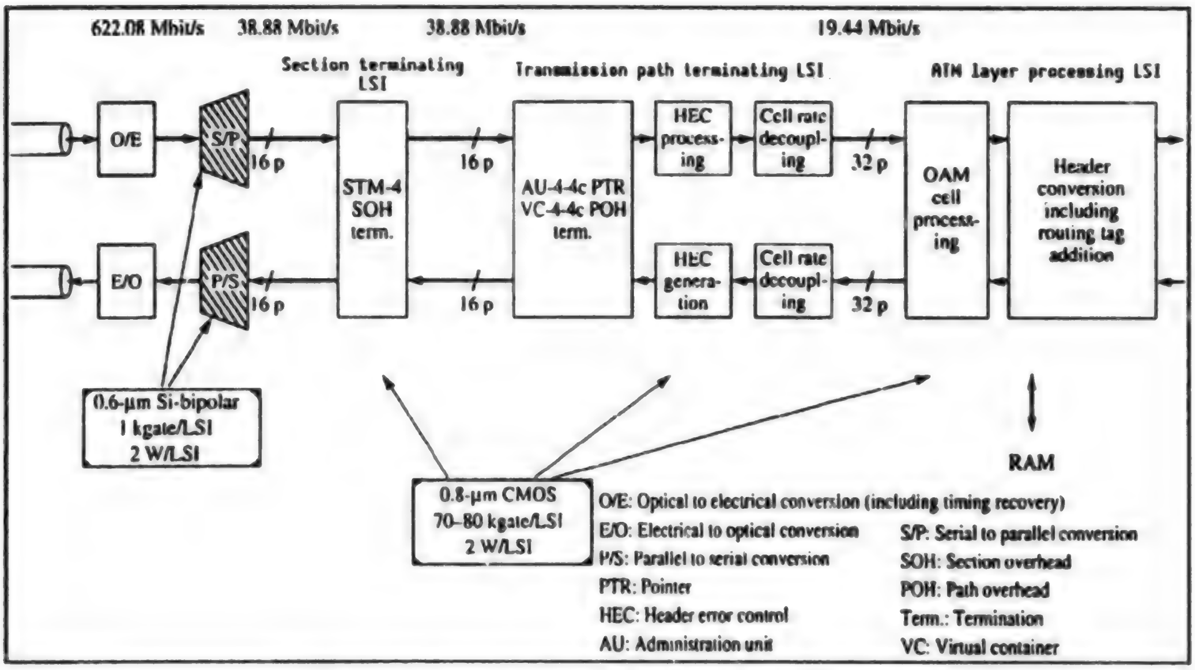

Figure 3. STM-4 Line Interface Card Configuration

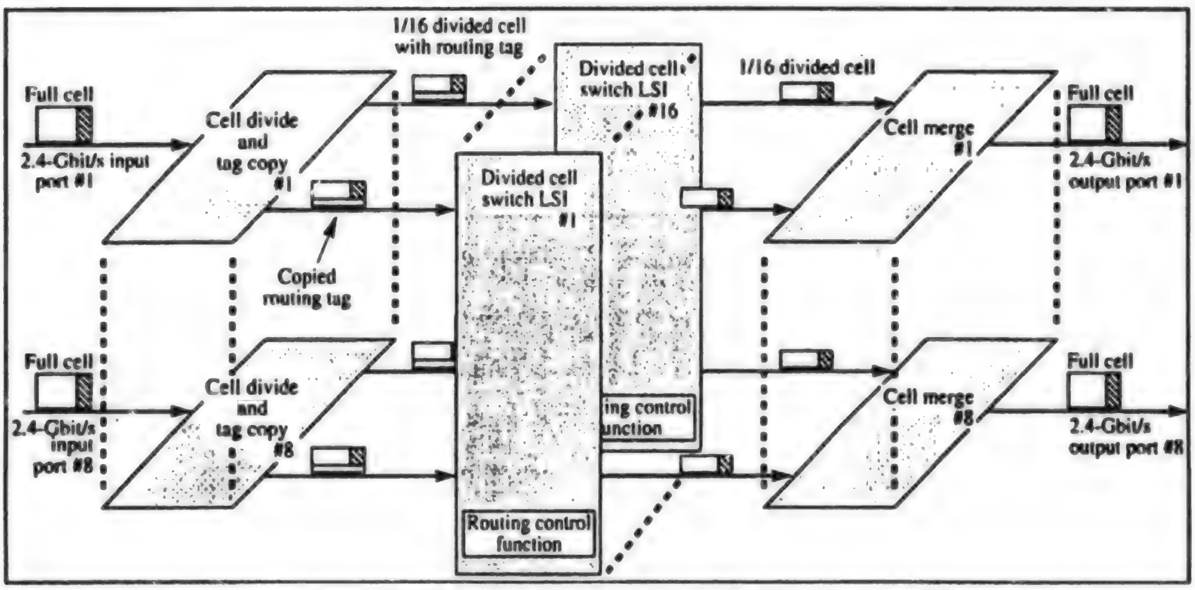

Figure 4. 2.4-Gbit/s Parallel Processing Switch Configuration

Operation, Administration, and Maintenance

The developed equipment supports the OA&M functions of the ATM layer to provide reliable network operations. In the ATM layer, the information for OA&M management, e.g., fault reporting messages, error detecting codes, as well as user data, must be transported by OA&M cells, while the OA&M management in the STM network is performed by section/path overhead bytes. Furthermore, in the B-ISDN environment, path bandwidth management is important to avoid traffic congestion in the network. If users intentionally or unintentionally exceed the allocated bandwidth, cells in the virtual path (VP) must be

discarded, otherwise the network would be overloaded. This bandwidth monitoring and discarding process is called policing, and resource management processes including bandwidth allocation and policing are called usage parameter control (UPC).

The developed equipment supports[5]:

(1) VP fault management using fault reporting cells

(2) VP performance management using performance monitoring cells

(3) VP performance testing using VP testing cells

(4) VP tracing using VP tracing cells

(5) Peak rate and average rate policing using the sliding window method and the two-phase jumping window method.[6]

In fault management and performance management, OA&M cell processing, such as error detection code calculation, is done on multiplexed levels using large capacity RAM with time-sharing, which allows the 4096 VPs of one transmission line to be simultaneously monitored. The UPC LSI also uses large capacity RAM with the time-sharing method and can handle the 256 VPs of one UNI line simultaneously. Performance monitoring cells and VP testing cells transport information about the sequence and the number of transmitted cells to determine the lost/misinserted cell count.

These management functions are installed in the ATM layer processing VLSIs in line interface cards, as shown in Fig. 3.

Implementation of the ATM Access Multiplexer

In this section, the function and configuration of a newly developed ATM access multiplexer with 150-Mbit/s 24 x 24 switch fabric are described.

As shown in Fig. 5, the ATM access multiplexer consists of subscriber line interfaces, intra-office interfaces, and a VP cross-connect switch fabric which multiplexes and connects subscriber VPs to the intra-office line.

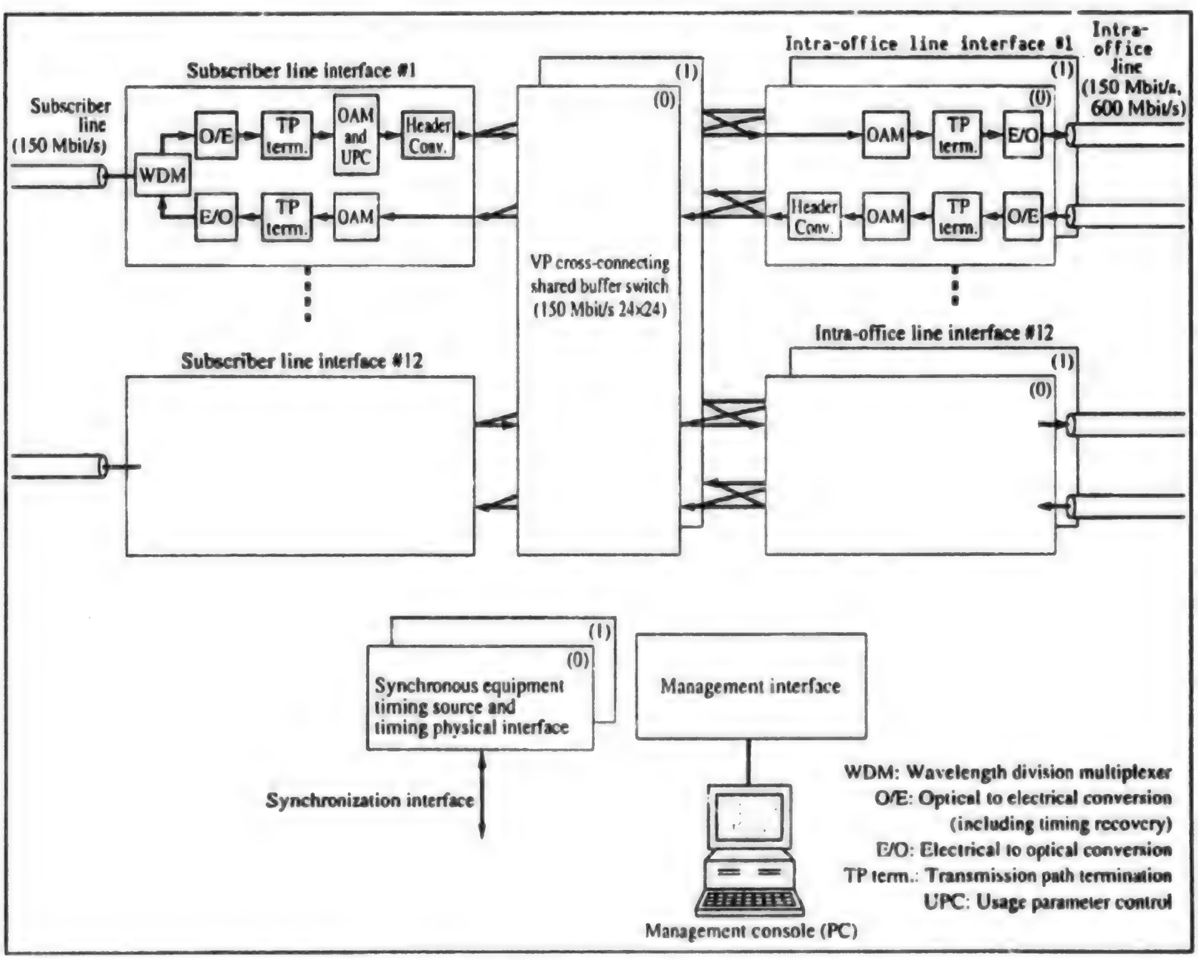

Figure 5. ATM Access Multiplexer Configuration

At the entrance to the network, a 32 x 32 shared buffer type switch, mentioned in the previous section, is suitable for the VP switch, because of its tolerance of bursty traffic. The subscriber line interface has a wavelength division multiplexer (WDM) for upstream and downstream multiplexing. The subscriber line interface has a UPC function.

The access multiplexer can handle 12 subscriber lines with STM-1 B-ISDN UNI, and 12 trunk lines for the STM-1 intra-office interface. As an intra-office line interface card, an STM-4 line interface card can also be used. All the functions except the subscriber interface have one-to-one redundancy. These functions are mounted in one shelf (600mm x 300mm x 375mm). Fig. 6 and Fig. 7 show the external view of the STM-4 line interface card, and the testing system for ATM access multiplexer respectively.

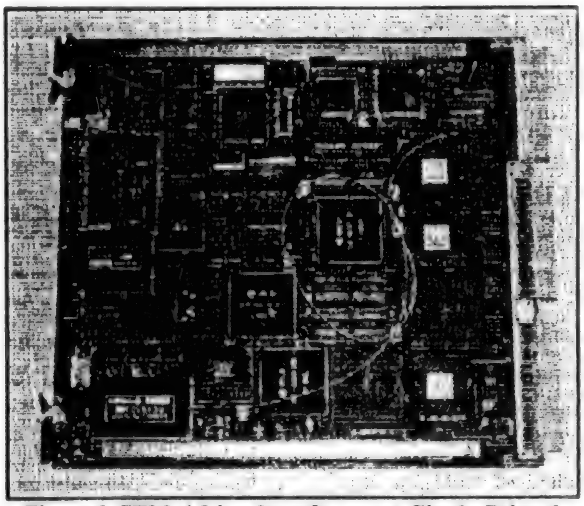

Figure 6. STM-4 Line Interface on a Single Printed Circuit Board. This card (330mm x 300mm) contains the functions shown in Fig. 3.

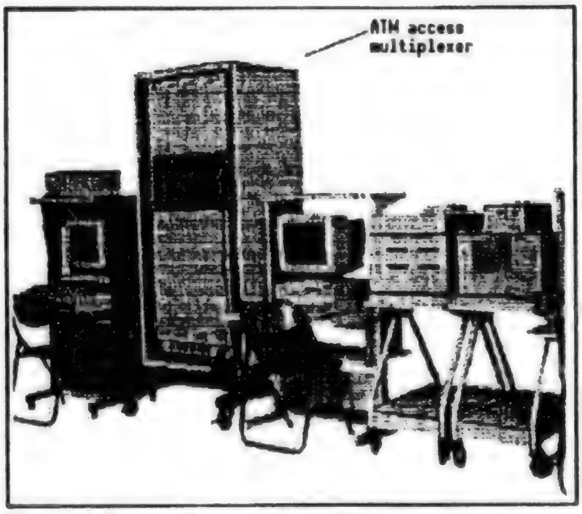

Figure 7. Testing System for ATM Access Multiplexer

Conclusion

Newly developed ATM equipment and the related technologies are described. Compact ATM equipment with OA&M functions are realized using 0.8-µm CMOS VLSIs and optical transmission modules using sophisticated ICs. A large capacity ATM switch fabric can be realized using parallel processing and a shared buffer technique. These results demonstrate the feasibility of B-ISDN for the coming age of new communication services.

Acknowledgement

The authors wish to express their gratitude to Mr. I. Tokizawa, Mr. K. Kikuchi and Dr. H. Ueda at Nippon Telegraph and Telephone Corporation for their useful discussions.

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Fiber-Optic Subscriber System Based on Passive Optical Network Architecture

43070117C Tokyo HITACHI REVIEW in English Apr 94 pp 53-58

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[FBIS Transcribed Text]

Abstract

A passive double star (PDS) fiber-optic subscriber system that provides narrowband ISDN services (called INS 64 and INS 1500 in Japan) has been developed under the direction of Nippon Telegraph and Telephone Corporation. This PDS system is economical because it allows multiple subscribers to share a single optical transmission line and central equipment unit. This system can also transmit video on the same optical fiber by wavelength

division multiplexing (WDM). For the optical interface module, a WDM chip is hermetically sealed together with LD and PD chips by adopting high-silica based optical-waveguide technology in order to miniaturize the system. Also, fast bit synchronization, TCM/TDMA control, and 16-channel multiprocessing functions have been implemented in LSI.

Introduction

Implementation of optical subscriber networks, which are expected to be the next-generation subscriber system infrastructure, is being studied. Optical subscriber networks must economically provide analog telephone, narrowband ISDN, and broadband services including video.[3]

Fig. 1 shows the configuration of a fiber-optic subscriber system based on passive optical network architecture.

The PDS system is suited for economical use because it connects multiple subscribers to a single optical transmission line through a star coupler, allowing them to share the same central office equipment unit. Also, video can be transmitted on the same optical fiber by wavelength division multiplexing (WDM).

The PDS system uses the time compression multiplexing (TCM) to implement bidirectional transmission through a single fiber. Signals from optical network units (ONUs) meet at the star coupler. This requires timing control to prevent one ONU's signals from overlapping with another ONU's signals. It also requires an encryption technique that allows de-encryption only for the ONU concerned. The distance between the star coupler and an ONU differs for each ONU. This requires an optical transmission technique that responds quickly to loss variation. (The detail is explained in the "Key Techniques" section.)

This paper shows the configurations of the SLT (subscriber line terminal) and ONU of the fiber-optic system we have developed. It further describes the key techniques of the system.

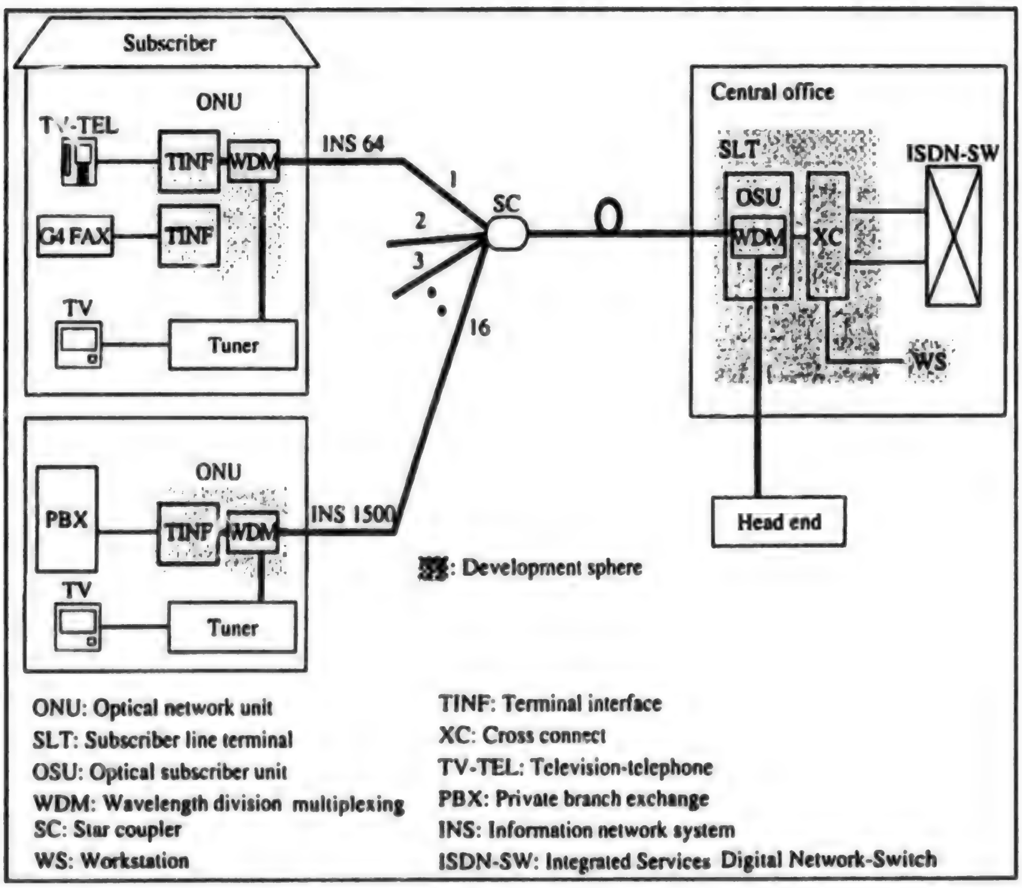

Figure 1. Configuration of a Fiber-Optic Subscriber System Based on Passive Optical Network Architecture

Table 1 shows the major specifications of the PDS system.

Table 1. Major Specifications of the PDS System

Item	Specifications
Provided service capacity	Maximum: 24 *B* Average: 12 *B* (for 16 branches) *B* = 64 kbit/s
Wavelength	1.3 μm
Transmission distance	7 km (for 16 branches)
Number of branches	16
Transmission speed	28 Mbit/s
Upstream/downstream multiplexing method	Time completion multiplexing (TCM)
Inter-ONU multiplexing method	Time division multiple access (TDMA)
Video distribution service	Wavelength division multiplexing (WDM) Wavelength: 1.5 μm

Structure of Subscriber Line Terminal (SLT)

Fig. 2 shows the configuration of the SLT. The following is a description of component functions.

(1) Optical subscriber unit (OSU)

The OSU performs the following functions:

- TCM/time division multiple access (TDMA) control
- WDM
- Fast bit synchronization and frame synchronization of upstream frames from 16 ONU

(2) Cross connect (XC)

The XC performs line setting for INS 64 services and INS 1500 services from the ISDN digital exchange. Line setting is performed for each B-channel (64 kbit/s).

(3) Multiplex/de-multiplex (MLDX)

The MLDX multiplexes signals from ISDN switch interface (ISDN SW INF) into the interface speed. It also de-multiplexes them in the reverse direction.

(4) ISDN SW INF

The ISDN SW INF interfaces with the ISDN digital exchange.

(5) Common unit (COM)

The COM performs the following functions:

- Terminal control (TC)
- Alarm control (ALM)
- Clock supply (CLK)

The terminal control block receives control data from the workstation (WS) and distributes it into the SLT. The data is for:

- Setting parameters under software control
- Testing
- Collecting administrative ONU control data.

The alarm control block gathers alarm information in the SLT and transfers it to the alarm collector.

The alarm control block distributes clock signals and frames to the SLT.

Structure of Optical Network Unit (ONU)

Fig. 3 shows the configuration of the ONU. The ONU is installed in a home or office. It consists of WDM, O/E and E/O similar to the OSU. There are two types of ONU with different terminal interface circuits (TINF): one terminates an INS 64 service line and the other an INS 1500 service line. Multiplexer (MUX) and demultiplexer (DMUX) combines the lower bit rate signals (INS 64 or INS 1500) to the line rate of 28 Mbit/s. TINF and MUX/DMUX are made by logic circuits. This logic circuit section of the ONU is mounted on one LSI chip. Power is supplied from a 100-volt AC outlet. A battery is provided to guard against AC power service interruption.

Connecting the tuner to the 1.5-μm ONU port enables reception of video distribution services.

Key Techniques-Control Circuit

(1) TDMA control

Fig. 4 shows time division multiple access (TDMA) control. TDMA applies to the upstream, and time division multiplexing applies to the downstream. For upstream and downstream multiplexing, time compression multiplexing applies.

Since signals from ONUs meet at the optical coupler, the OSU must control the timing for transmission output from each ONU, so that signals from ONUs do not overlap. To implement this, the OSU assigns a reference transmission output timing for each ONU at the start of communication. The longer the fiber length from the optical coupler to an ONU, the longer the delay in response from the ONU. The OSU detects this delay time and reassigns a transmission output timing for the ONU. Then, it puts the delay control bits on the downstream. This operation is performed for each ONU. This control reduces the protection time between upstream and increases the total transmission capacity for the ONUs.[2]

(2) Bit synchronization

Short burst data streams from ONUs are received by the OSU. The bit phases of these streams are different from each other. Bit synchronization at the OSU must be established within one short burst upstream signal duration.

Fig. 5 shows the fast bit synchronization circuit block diagram. Four clock pulses with different phases are generated from the master clock, and re-time the input data. The detection circuit then determines which clock pulse phase is best matched to the input data.

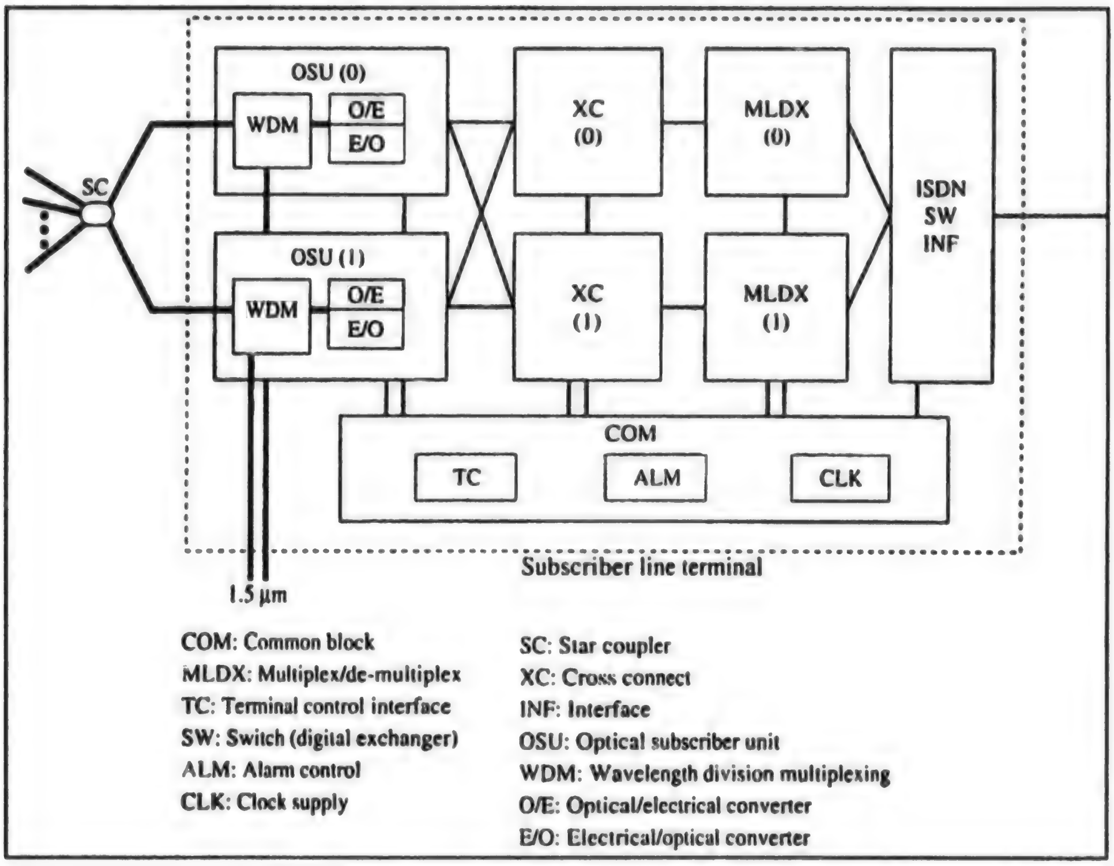

Figure 2. Configuration of the Subscriber Line Terminal

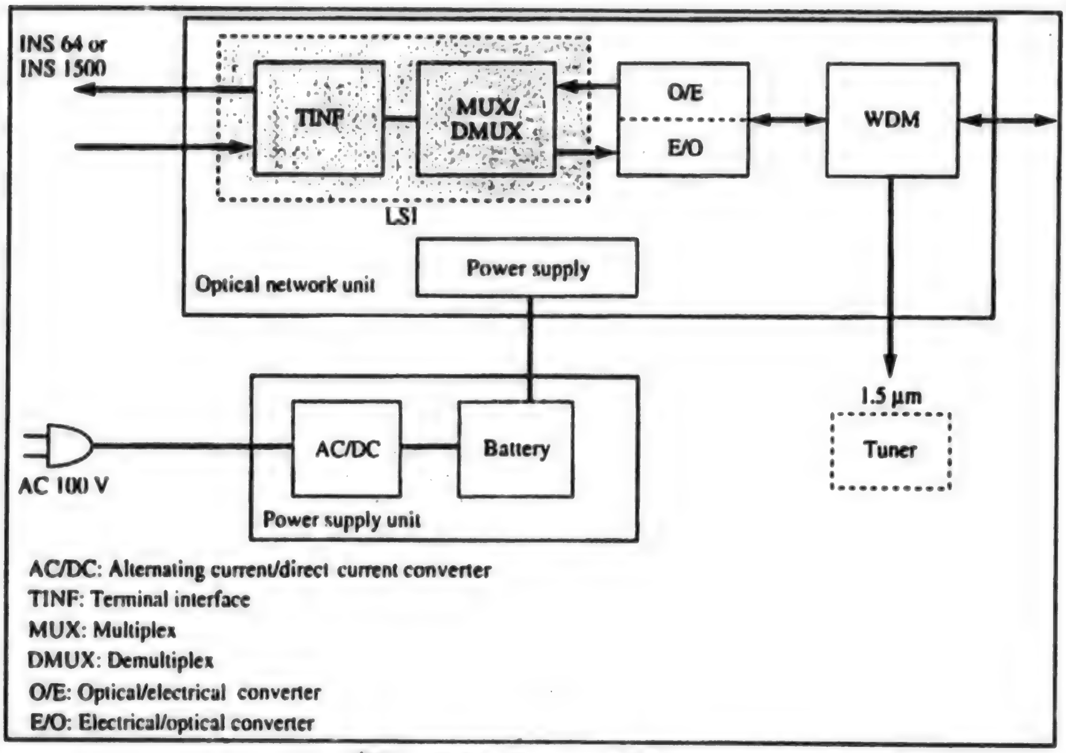

Figure 3. Configuration of ONU

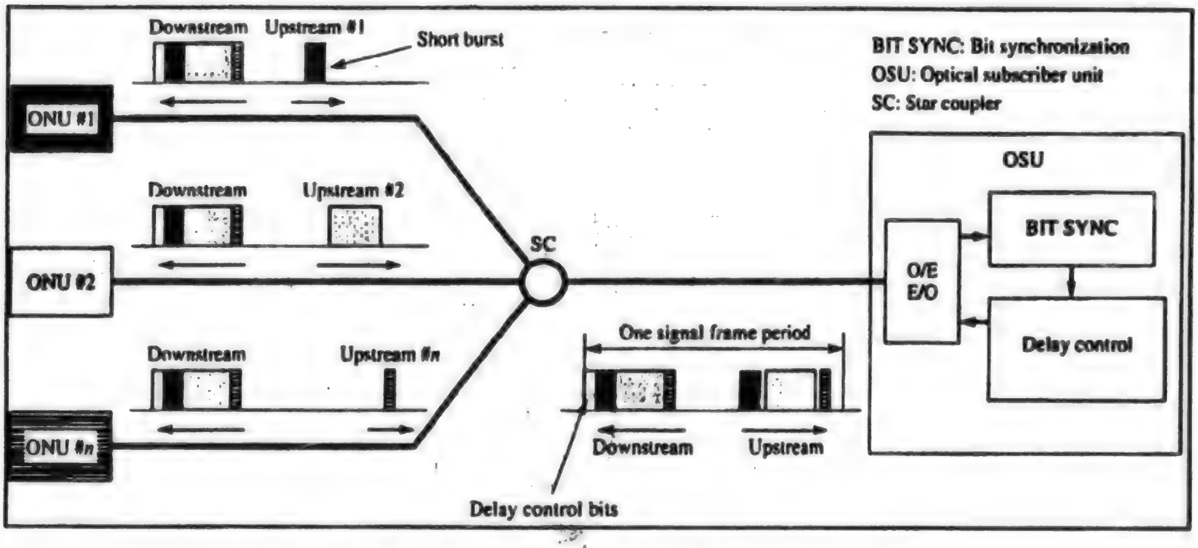

Figure 4. Time Division Multiple Access (TDMA) Control

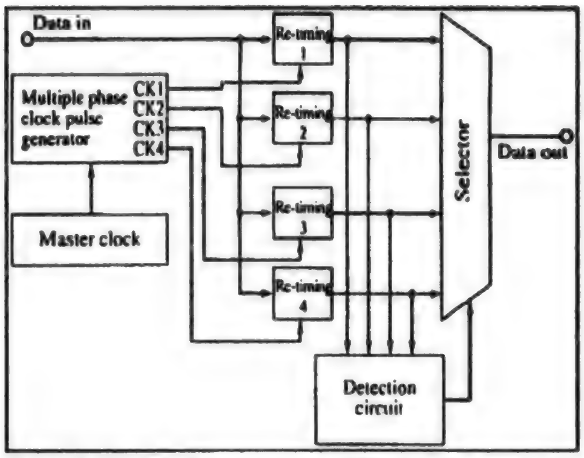

Figure 5. Fast Bit Synchronization Circuit Block Diagram

This fast-bit synchronization circuit can synchronize with the input data within several bit cycles. It can also be implemented as an all-digital circuit.

Fig. 6 shows the principle of the fast-bit synchronization circuit. The detection circuit in Fig. 5 detects the polarity changes of the input data using exclusive-ORs (EX-ORs). Once an EX-OR's output changes from "0" to "1," this data is held by a B-register in detection circuit. Even if the EX-OR's output is not "1" in the next period, B-register output remains "1." The optimum phase clock pulse is selected by decoding the four bit B-register output pattern. This bit-synchronization can be achieved within several bit times. By using this optimum phase clock pulse, the data latched nearest the center of the input bit interval is selected.

(3) Key Techniques-Optical Interface Module

The optical interface module employed in PDS subscriber systems have various requirements such as fast response, high sensitivity, wide optical dynamic range and compactness. Compact optical interface modules, consisting of an optical WDM sub-module, hybrid-integrated transmitter (TX) and receiver (RX) circuits, have been developed in order to realize these requirements.

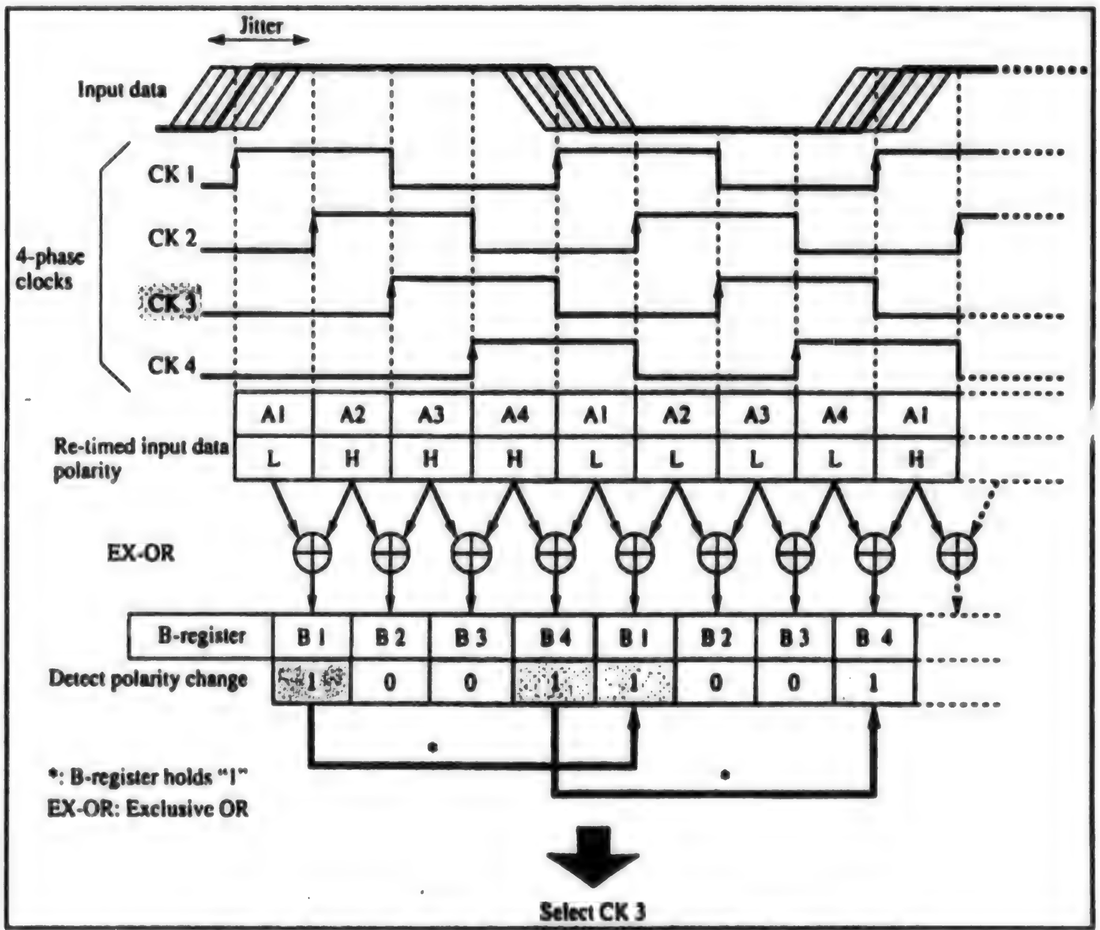

Figure 6. Operation Principle of the Fast-Bit Synchronization Circuit

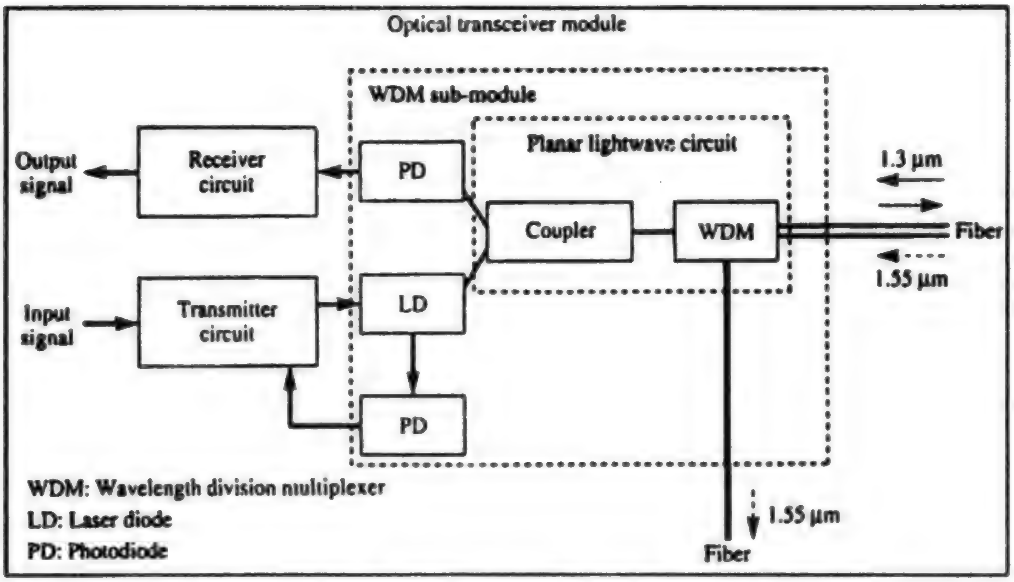

Figure 7. Functional Block Diagram of the Optical Interface Module. The optical interface module consists of a WDM sub-module, hybrid-integrated transmitter and receiver circuits.

The functional block diagram of the optical interface module is shown in Fig. 7. To miniaturize the module, the planar lightwave circuit is integrated in a single chip by adopting high-silica based optical-waveguide technology.[1] It is comprised of a 3-dB optical directional coupler for 1.3-µm bidirectional transmission through a single fiber and optical WDM device for the wavelength of both 1.3 µm and 1.55 µm. The lightwave circuit chip is hermetically sealed with an LD and two PDs (detector and monitor), in a single package.

The block diagram of the transmitter circuit is shown in Fig. 8. In an ONU transmitter, the current switch was turned off externally by TX/RX mode signal in order to set the transmitter to a stand-by state during the downstream signal receiving. Optical output power was automatically controlled utilizing a photo-current detected by a monitor PD placed on the back-side of the LD in the WDM sub-module. As an automatic power control (APC) scheme, the non-bias drive current control method was chosen to ensure stable transmitter operation. In burst signal transmission, the marked ratio of transmitted signal stream varies widely. Accordingly, a fast response peak detector with a large time constant of 1 ms was introduced to produce a control signal which compares an incoming burst signal with a signal detected by the monitor PD.

In the receiver circuit, high-speed automatic gain control (AGC) and automatic threshold control (ATC) techniques were developed to realize high sensitivity, wide optical dynamic range and fast response for incoming burst signals. The circuit configuration is shown in Fig. 8. A high-speed AGC amplifier was adopted as a means

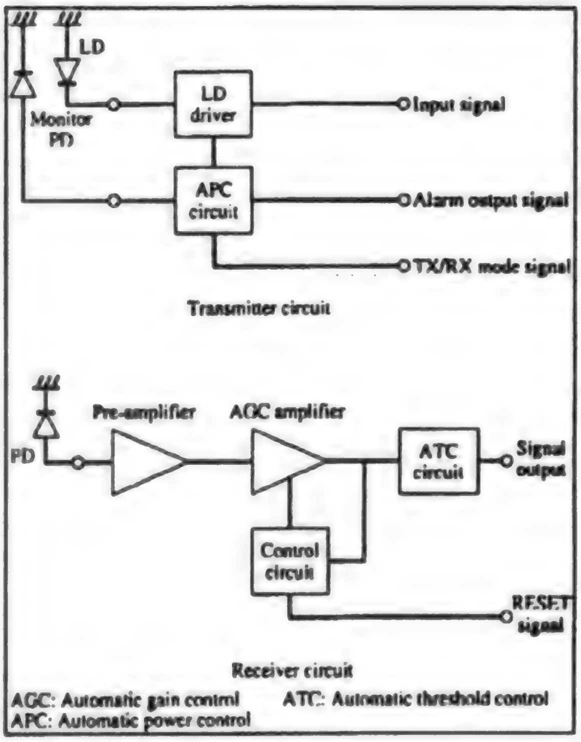

Figure 8. Block Diagram of Receiver Circuit. Fast response AGC and ATC techniques are introduced for high-quality burst signal transmission.

for gain control in order to make the receiver quickly reach on-state stability and to attain a wide optical dynamic range. For the AGC amplifier, a wide linear operation region is required because the pulse width distortion produced in the amplifier degrades the receiver sensitivity. An ATC circuit was devised to obtain high sensitivity and to keep the fast response of the receiver irrespective of the received optical power level. Using the ATC technique, the optimum reference level was achieved over a wide optical dynamic range. Also, a pulse distortion of less than +/- 10 percent was obtained.

The fabricated optical interface module is shown in Fig. 9. The WDM sub-module, transmitter and receiver circuits were electrically connected by soldering. The module has a geometric size of L: 80mm x W: 50mm x H: 9mm (volume: about 36 cc).

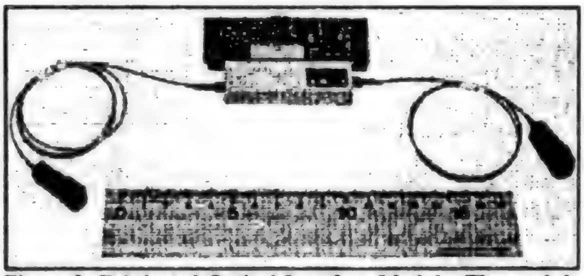

Figure 9. Fabricated Optical Interface Module. The module has a geometric size of L: 80mm x W: 20mm x H: 9mm.

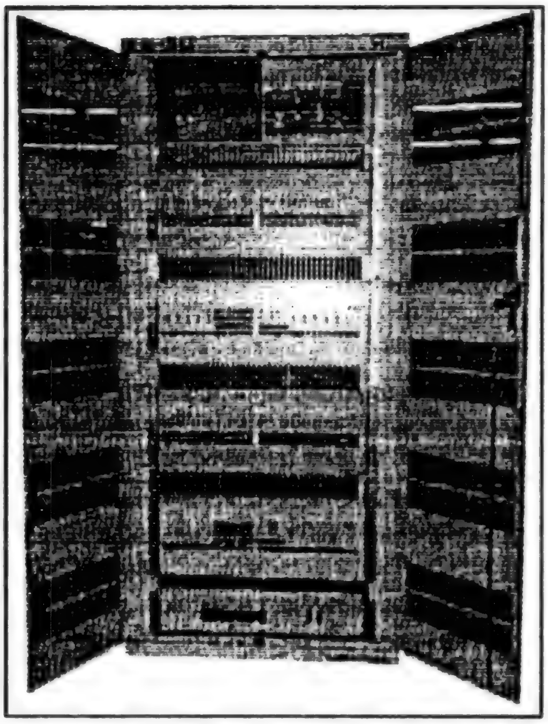

Figure 10. A Subscriber Line Terminal (SLT). The SLT connects 300 ONUs. Dimensions: 800mm (W) x 600mm (D) x 1800mm (H).

Subscriber Line Terminal

By using these techniques, the SLT is realized as shown in Fig. 10. The top row in the cabinet has the common unit. The second and fourth rows in the cabinet have the optical subscriber unit which has the OSU and the XC. The third and fifth rows in the cabinet have the ISDN SW INF unit. The SLT connects 300 ONUs for INS 64 narrowband ISDN service or it connects 150 ONUs for INS 1500 narrowband ISDN service.

Conclusion

A passive double star (PDS) fiber-optic subscriber system that provides narrowband ISDN services has been developed. LSI has been used to implement the major techniques of this system, i.e., fast-bit synchronization, time division multiple access (TDMA) control, and subscriber multiplexing/de-multiplexing. For the optical interface module, a WDM chip is hermetically sealed together with LD and PD chips to miniaturize the system. The system can also transmit video by wavelength division multiplexing (WDM). There are great expectations for PDS optical subscriber systems to develop which will allow for economical configuration of optical subscriber networks.

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600-Mbit/s Multiplexing Terminal Equipment With an ITU-T Standard Transmission Interface

43070117D Tokyo HITACHI REVIEW in English Apr 94 pp 53-58

[Article by Yukio Minami and Katsumasa Ono, Telecommunications Division, Hitachi, Ltd.; and Yasuhiro Yamada, Fiberoptics Division, Hitachi, Ltd.]

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Abstract

The transmission systems of New Common Carriers (NCCS) and electric power companies have used pulse stuffing transmission equipment for their trunk lines. Since 1992, TTNet (Tokyo Telecommunication Network) started introducing into their network synchronous digital hierarchy (SDH) equipment that was standardized by ITU-T in 1988. In line with this trend, Hitachi, Ltd. has developed 600-Mbit/s SDH equipment. This equipment consists of one bay and multiplexes 1.5-Mbit/s, 2-Mbit/s, 6-Mbit/s, and 8-Mbit/s low-speed signals of the old hierarchy and 50-Mbit/s and 150-Mbit/s low-speed signals of the new hierarchy into 600-Mbit/s high-speed signals to be transmitted over the transmission path. This equipment features the following and can be used as the core of future NCC trunk line transmission equipment: (1) It can multiplex any combination of old and new low-speed signals into high-speed signals; (2) Natural convection cooling eliminates the need for fan maintenance; (3) Since the supervisory and control signals are superimposed on the main signal, a separate network for supervision and control is unnecessary.

Introduction

Since 1989, NTT (Nippon Telegraph and Telephone Corporation) has been installing synchronous digital hierarchy (SDH) transmission equipment that uses the new synchronous transmission interface standardized by ITU-T in 1988 (then CCITT).[1] On the other hand, New Common Carriers (NCCS) have different requirements: a cost-effective equipment configuration, reduction in equipment installation space and natural convection cooling, due to the difference in the network scale.

This article describes the 600-Mbit/s multiplexing terminal equipment that Hitachi developed for NCC and private networks such as those installed in electric power companies.

Configuration of the Transmission System and Equipment

Although the existing trunk transmission lines of NCCs and electric power companies are 400-Mbit/s or 1.6-Gbit/s pulse stuffing transmission lines, the trend is toward SDH networks defined in ITU-T recommendations (G.707, G.708, and G.709). The developed 600-Mbit/s multiplexing terminal equipment applies to these SDH networks. Fig. 1 shows how this equipment is used for a transmission system.

This equipment multiplexes digital primary (1.5 Mbit/s), digital second order (6 Mbit/s), Japanese intra-office 8 Mbit/s, and Japanese intra-office 2-Mbit/s low-speed signals, and SDH synchronous transport module level 0 (STM-0: 50 Mbit/s) and STM-1 (150 Mbit/s) signals into STM-4 (600 Mbit/s) signals and transmits the resultant signals optically.

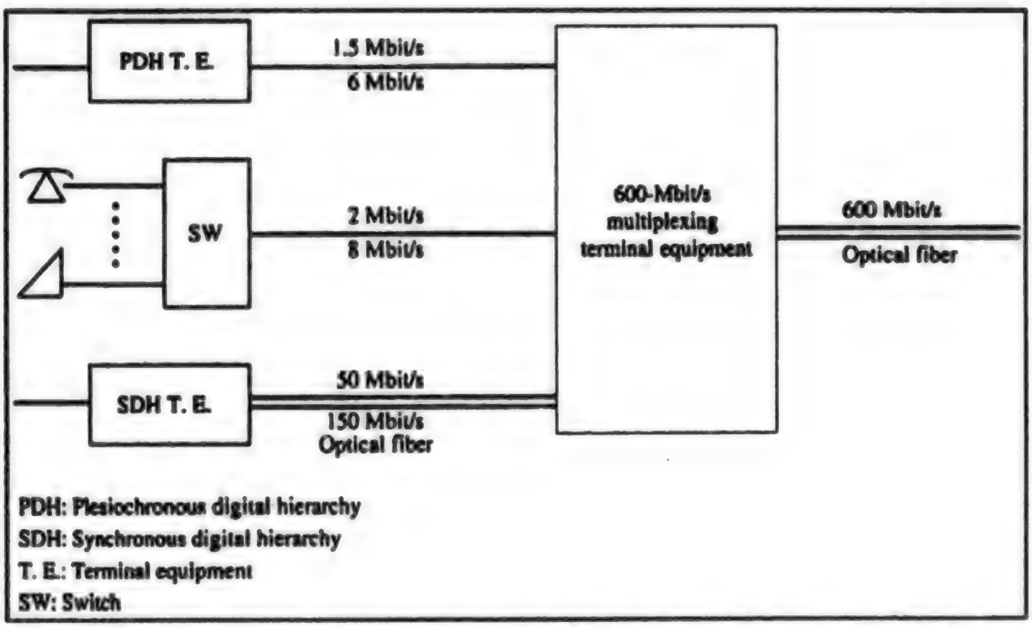

Figure 1. Transmission System Example. Japanese domestic 1.5-Mbit/s, 6-Mbit/s, 2-Mbit/s, and 8-Mbit/s interfaces are used.

Fig. 2 is a block diagram of this equipment. The equipment consists of low-speed section I, low-speed section II, a high-speed multiplexing section, and a common section.

The function of each section is as follows.

As shown in Fig. 3 (a), low-speed section I accommodates 1.5-Mbit/s and 6-Mbit/s signals from the existing transmission equipment and 2-Mbit/s and 8-Mbit/s signals from digital exchanges, and multiplexes and converts them into the 150-Mbit/s common interface for the high-speed multiplexing section. (A system (SYS) implementing this function is housed in one 650mm wide x 200mm high unit.)

Low-speed section II accommodates 50-Mbit/s and 150-Mbit/s SDH signals, terminates the transmission lines, and converts the signals into the connection interface for the high-speed multiplexing section, as shown in Fig. 3 (b). (One unit accommodates two SYSs.)

The high-speed multiplexing section multiplexes the low-speed signals above, terminates the STM-4 overheads, and connects to a 600-Mbit/s optical transmission line, as shown in Fig. 3 (c). (One unit accommodates one SYS.)

The common section supplies clock signals to each section and supervises and controls the equipment. (This section is accommodated in one unit.)

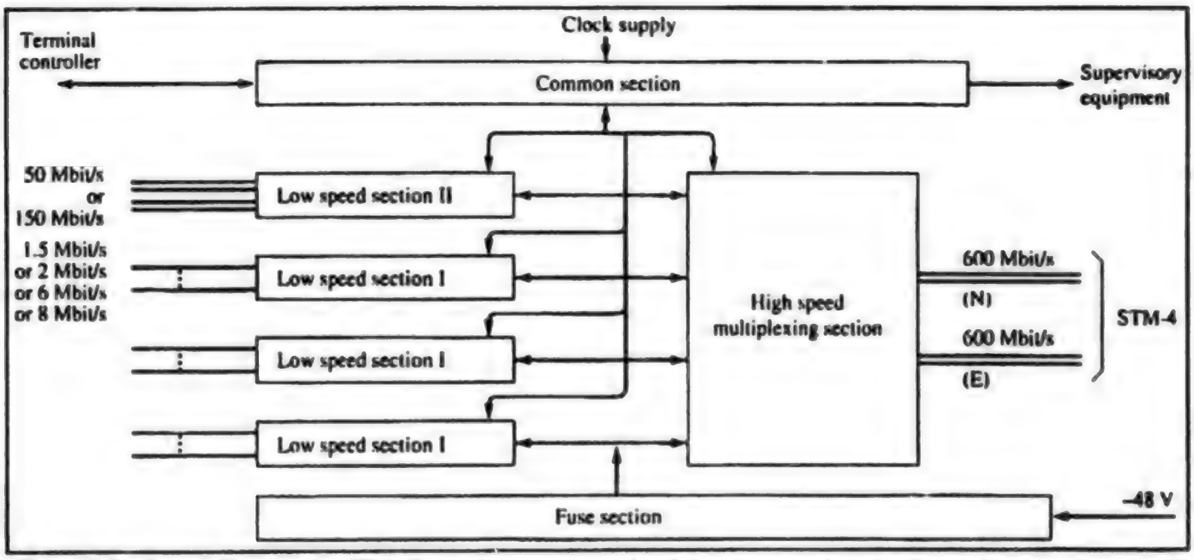

Figure 2. Equipment Construction. This figure shows an example of three low-speed section I and a low-speed section II.

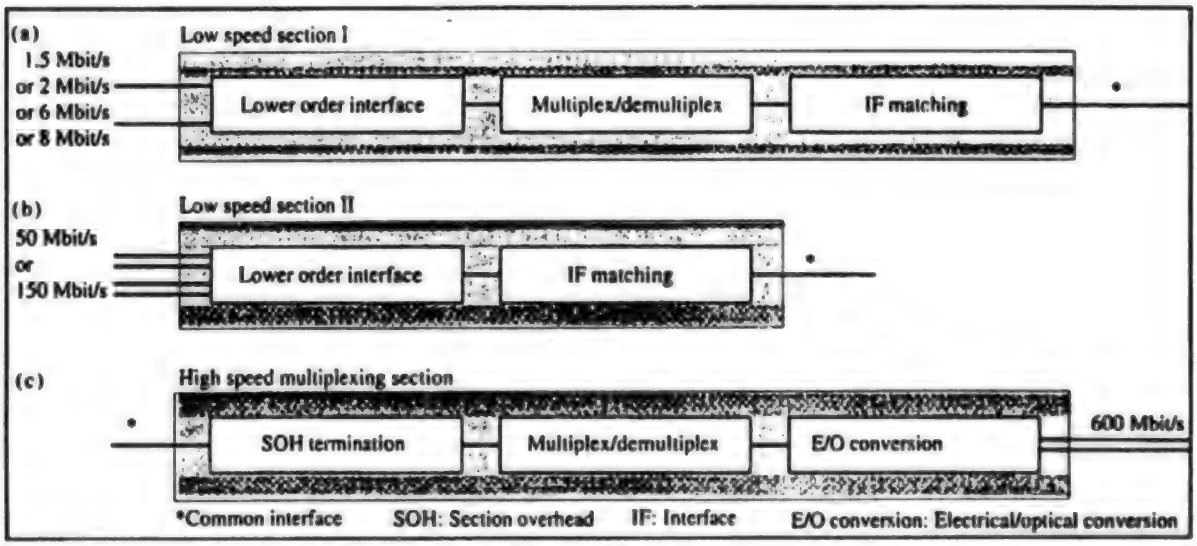

Figure 3. Block Diagram

Fig. 4 shows the bay mounting configuration of the 600-Mbit/s multiplexing terminal equipment.

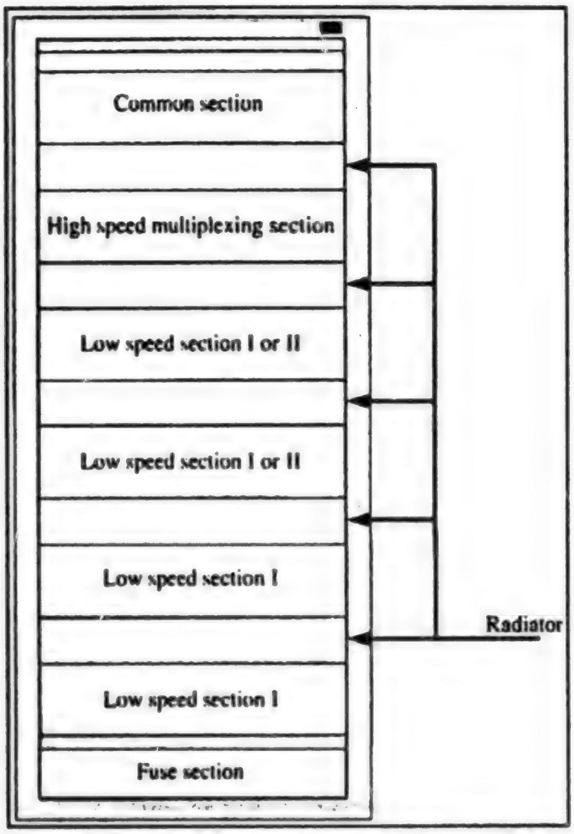

Figure 4. Bay Construction. One frame accommodates one 600-Mbit/s signal.

Equipment Features

The 600-Mbit/s multiplexing terminal equipment is trunk line transmission equipment that performs STM-4 (600 Mbit/s) synchronous transmission complying with an ITU-T standard interface. It allows large-capacity transmission of up to 8064 channels of telephone traffic. The following are the major features of this equipment:

(1) In Hitachi's conventional SDH equipment, separate bays are required for the unit that accommodates 1.5 Mbit/s and other speeds of existing signals, multiplexes them into 150-Mbit/s signals and transmits the resultant signals; and for the unit that accommodates 150-Mbit/s and other SDH signals, multiplexes them into 600-Mbit/s signals and transmits the resultant signals.[2] The multiplexing terminal equipment can accommodate low-speed section I and low-speed section II in the same frame, as mentioned above, so two bays are no longer necessary. In addition, these low-speed sections can be combined as desired within the 600-Mbit/s transmission capacity, as shown in Fig. 4.

Using this equipment, conventional digital equipment can be interconnected with SDH cross-connect equipment and the SDH network. Since either low speed section I or II can be added as desired into one bay according to office requirements, floor space can be saved.

(2) Maintenance is easy because the equipment is provided with the following functions:

(a) The key parts, such as the main signal section and power section, are fully redundant. Upon a failure, they are diagnosed and switched automatically.

(b) To manage the digital transmission quality, detailed alarm information is output automatically and history management of momentary errors is possible.

(c) The equipment operating parameters (transmission code, active system, etc.) can be set, the operating state can be monitored and the operating conditions can be changed remotely under software control.

(3) To reduce power consumption, a special thermal design is used to eliminate the need for a fan in this equipment, which improves its maintainability.

(4) The supervisory/control signal is superimposed on the main signal, so no dedicated network is necessary for supervision and control.

(5) A 1.3-μm semiconductor laser and GE-APD (avalanche photodiode) are used as the optical transmitter and receiver elements, respectively. This enables 40-km repeaterless transmission over a single-mode optical fiber.

Equipment Overview

Table 1 lists the major specifications for the 600-Mbit/s multiplexing terminal equipment.

Table 1. Equipment Specifications

Item		Specification
Number of channels		8064 channels/frame
Interface	Higher order	STM-4 (600 Mbit/s) x 1
	Lower order*	(1) STM-1 (150 Mbit/s) x 1**/SYS (2)STM-0 (50 Mbit/s) x 3**/SYS (3) 1.5 Mbit/s x 44**/SYS (4) 6 Mbit/s x 21**/SYS (5) 2 Mbit/s x 34**/SYS (6) 8 Mbit/s x 17**/SYS
Redundancy	Higher order IF Lower order IF Power card	1:1 N:1 N:1
Optical transmission (600 Mbit/s)	Light emitting device Optical transmitting power Light receiving device Minimum receivable power	InGaAsP LD/1.3μm +3 dBm Ge-APD -34 dBm
Cooling method		Natural convection

*One bay accommodates four systems by combining interfaces (1)-(6).

**Each figure designates the maximum number.

The equipment is housed in a new type of bay 650mm wide, 500mm deep and 2300mm high. To reduce power consumption, this equipment uses for its high-speed multiplexing section GaAs LSIs that consume very little power and CMOS LSIs for low speed parallel-processing of Section Overhead (frame alignment, phase matching, signal format conversion, error rate detection, alarm detection, etc.). In addition, natural convection cooling is used to cool the bay by distributing the power consumption so heat does not concentrate on a specific card.

Fig. 5 shows a photo of the terminal equipment.

The top shelf of the frame is the common section, the 600-Mbit/s high-speed multiplexing section is installed on the second shelf, and low-speed sections are installed on the four lower shelves.

Any combination of existing signals and STM-0/STM-1 signals can be accommodated in the low-speed sections within the limit of the 600-Mbit/s capacity.

Another feature of this equipment is that long-distance repeaterless transmission over 40 kilometers is implemented by using a high-power semiconductor laser with a 1.3-μm wavelength for the 600-Mbit/s optical transmitter module. The minimum receivable power of the optical receiver module is under -34 dBm. Fig. 6 shows the error rate characteristics of the optical receiver module. The minimum receivable optical power satisfies the specification from 0 to 400°C.

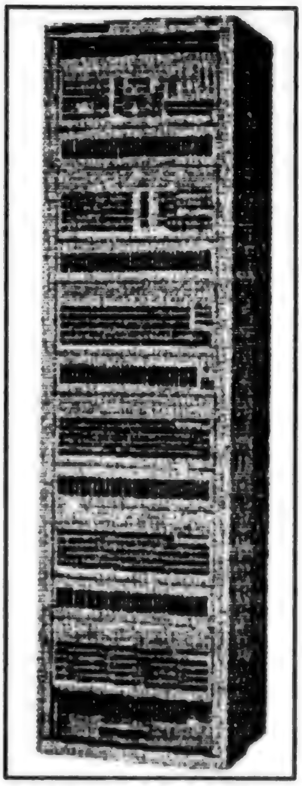

Figure 5. 600-Mbit/s Multiplexing Equipment. Equipment physical dimensions are 650mm wide, 500mm deep and 2300mm high.

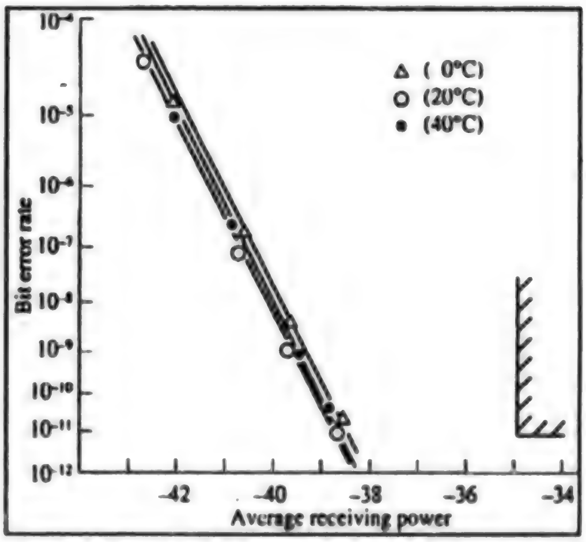

Figure 6. Error Rate Characteristics. This figure shows the bit error rate characteristics of the 600-Mbit/s optical receiver. The hatched area indicates the out of spec. region.

Conclusion

We have developed multiplexing terminal equipment that allows 600-Mbit/s transmission based on an internationally standard interface. A mixture of existing interface signals used in conventional digital equipment and SDH interface signals can be accommodated in the same bay, saving floor space. The fan-less natural convection cooling of the bay, together with equipment redundancy eases maintenance. Also, operation is simplified by including features such as remote supervision and control, automatic failure diagnostics, and automatic switchover upon failures. The first three lots of this equipment were delivered to TTNet (Tokyo Telecommunication Network) in September 1992. They have operated smoothly to date.

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Fiber-Optic Transmission Equipment Designed for SONET Systems

43070117E Tokyo HITACHI REVIEW in English Apr 94 pp 63-66

[Article by Hiroyuki Fujita, Hiroki Koyama, and Yoshihiro Ashi, Telecommunications Division, Hitachi, Ltd.]

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Abstract

In existing asynchronous networks in the U.S., all vendors have so far used proprietary, non-standard techniques for optical transmission systems. As a result, different vendors' optical equipment could not easily communicate with each other. The only way to communicate between different vendors' equipment was to convert from optical signal to the asynchronous electrical standard interfaces of DS-1 and DS-3. This was very expensive and complex. SONET provides an answer for eliminating these problems and allows for the establishment of an advanced network. We have developed the OC-3 MUX/ADM as next-generation SONET equipment. It supports multiple self-healing ring topologies which are software reconfigurable. This new equipment achieves a simple, flexible, survivable and cost-effective network.

Introduction

Hitachi's SONET product family is designed for network evolution into the 21st century. Based on the synchronous optical network (SONET) standard, the Hitachi product family creates a more sophisticated network which enables a network provider to simplify network operations, improve network survivability, and reduce operation and capital costs.

SONET is a North American fiber optic telecommunications network standard which has been adopted by the American National Standards Institute (ANSI). Hitachi offers the SONET product family, which encompasses a wide range of SONET products for economical enhancement and expansion of the fiber infrastructure. Below, the OC-3 product (OC-3 MUX/ADM-Multiplexer/Add-Drop-Multiplexer), which is from the Hitachi SONET product family, is described (SONET OC-3 is equipment to SDH STM-1, i.e., synchronous digital hierarchy, synchronous transport module-1 of ITU-T) ([International Telecommunications Union-Telecommunications Standardization Sector], formerly CCITT [International Telegraph and Telephone Consultative Committee]).

The benefits of the OC-3 MUX/ADM are as follows:

(1) Network simplification

The OC-3 MUX/ADM economically provides capabilities which once required an assortment of asynchronous equipment. The existing asynchronous interfaces, 1.5 Mbit/s (DS-1) and 45 Mbit/s (DS-3), as well as future synchronous mapping can be accommodated by virtual tributaries (VTs) and synchronous transport signals (STSs), respectively, for transmission over the SONET fiber network. The OC-3 MUX/ADM achieves substantial simplification by eliminating asynchronous multiplexers, fiber terminals, cross-connects and so on, because it is able to carry any desired amount of bandwidth from one point to another without the other multiplexers at intervening points.

(2) Network flexibility and survivability

The OC-3 MUX/ADM supports a wide variety of network applications, including point-to-point, add/drop chain, ring and hubbing because of its add/drop and cross-connect functions. The functionalities of the Hitachi SONET products are software-reconfigurable. The cross-connect function can offer network providers the ability to optimize bandwidth utilization and to allow easy control of bandwidth provisioning, thus enabling the configuration of a cost-effective and flexible network. With an add/drop function that can realize self-healing ring architectures which protect well against fiber cable or equipment failures, the Hitachi SONET products go a step further in survivability.

(3) Powerful OAM&P

The operation, administration, maintenance and provisioning (OAM&P) of the OC-3 MUX/ADM brings to the user powerful testing, high reliability, and excellent maintenance functionally with such capabilities as traffic and performance analysis, self-healing and bandwidth control. The Hitachi SONET product family has a user friendly craft interface and an operation systems

interface which is transaction language 1 (TL 1) compliant with Bell Communications Research (Bellcore) standards. The operations system (OS) interface will be able to evolve from TL 1 to common management information service element (CMISE) which is telecommunication management network (TMN) standard and open systems interconnection (OSI) protocol standardized by Bellcore and ITU-T.

System Outline

The OC-3 MUX/ADM is a SONET OC-3 transport system that combines basic DS-1 and DS-3 with a variety of advanced functions for economical use and high reliability in inter-office and local loop networks. It has a wide variety of network applications, including terminal, add/drop, 2-fiber ring and 4-fiber ring. It consists of a single shelf which can support flexible combinations of low speed DS-1 and DS-3. OS options include TL 1/X.25, telemetry byte oriented serial (TBOS), or parallel telemetry, with upgradability to OSI/CMISE.

A key factor in making a system easy to use is its human interface. OAM&P of the OC-3 MUX/ADM brings to the user powerful testing (loopback, drop/insert/monitor), high reliability (automatic identification of a failure card by diagnostics, self-healing control) and excellent maintenance functionality (card inventory management, ADM, equipment parameter control by software strap, alarm & switch state history storage, etc.).

Network survivability is becoming more and more important for network providers as the number of business customers using public networks for leased line and other services increases. Hitachi's OC-3 MUX/ADM is the ideal building block for self-healing 2- and 4-fiber ring networks and even provides additional cross-connect capability for ring interworking and other options. Extensive performance monitoring allows carriers to ensure high levels of quality and reliability of service.

Network Application

The first application to be described is in the feeder portion of the network. The OC-3 MUX/ADM is well-suited for application to the local loop network. A generalized view of an existing asynchronous network is shown for reference in Fig. 1. Asynchronous DS-1s and DS-3s are fed directly to the office, or are multiplexed into higher speed asynchronous signals and transmitted optically to the local office. The first OC-3 MUX application to the existing network, shown in Fig. 2, is a direct application to that network and replaces asynchronous optical transmission equipment. In the second application, the network is further extended and VT 1.5 and STS-1 grooming (across entire STS-3) capability is added by implementation of add/drop functionality as illustrated in Fig. 3. The third application is shown in Fig. 4. By using the technique of self-healing rings (SHR-2-fiber ring or 4-fiber ring), high system reliability and low cost fiber cable installation can be achieved.

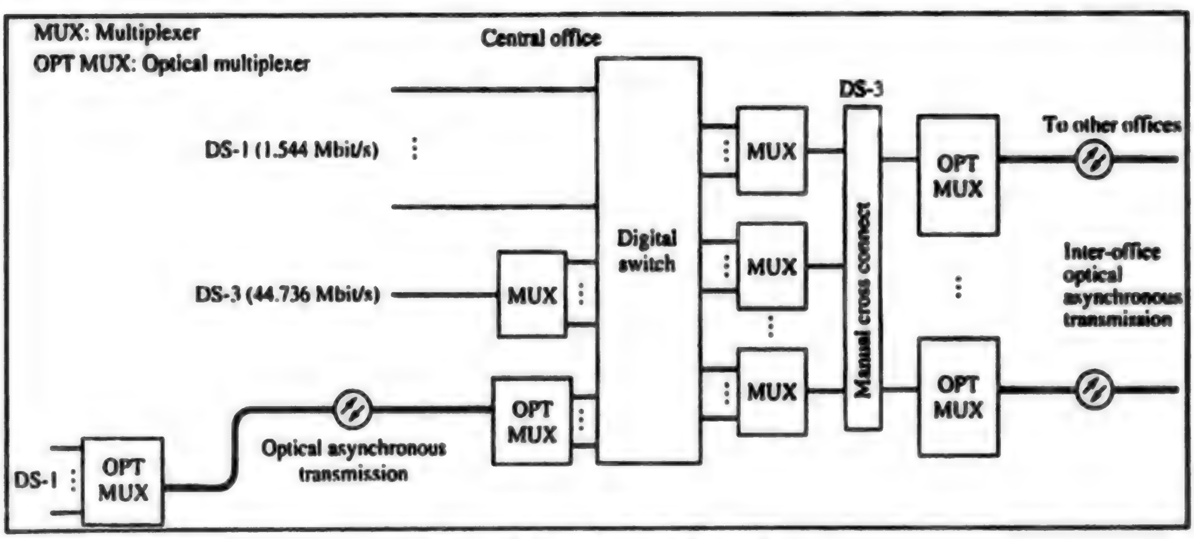

Figure 1. Asynchronous Network

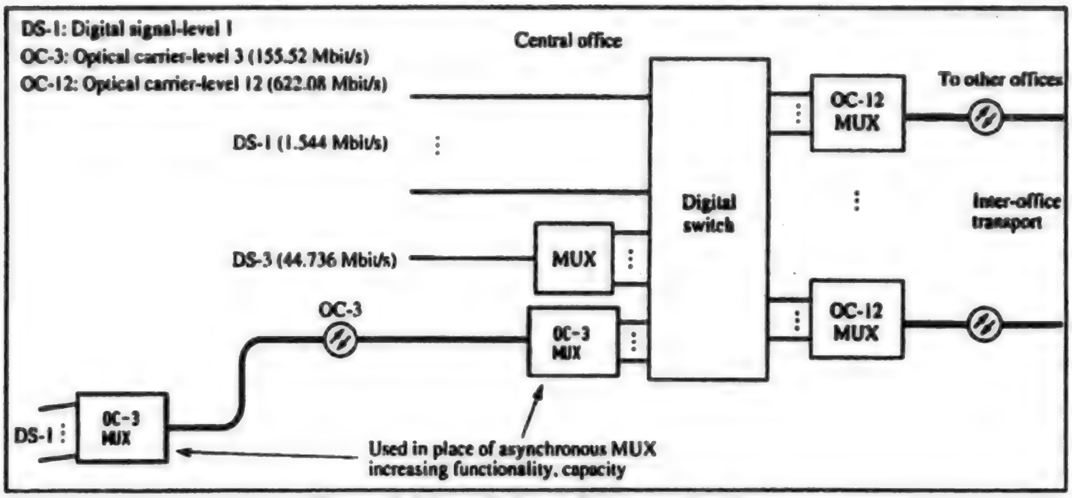

Figure 2. Direct Point-to-Point Application

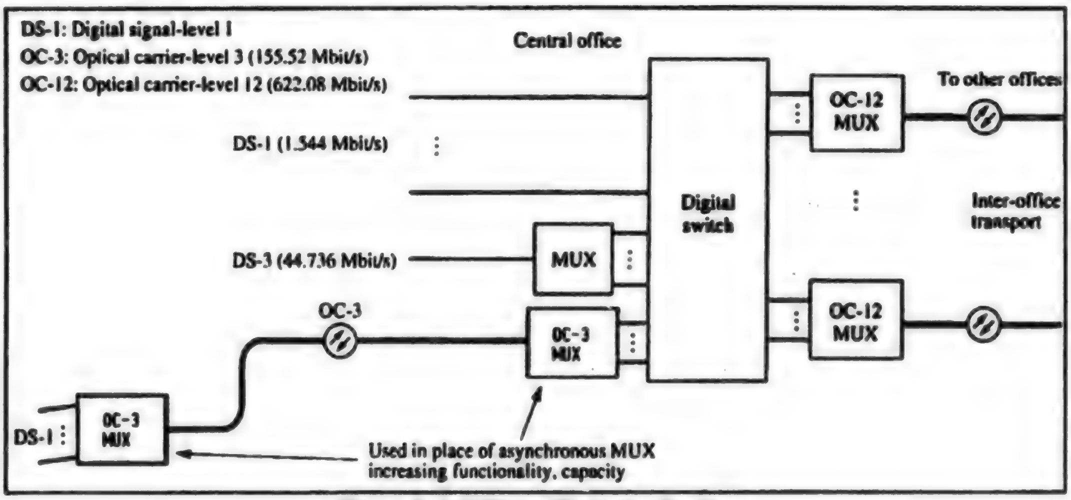

Figure 3. Add/Drop Chain Application

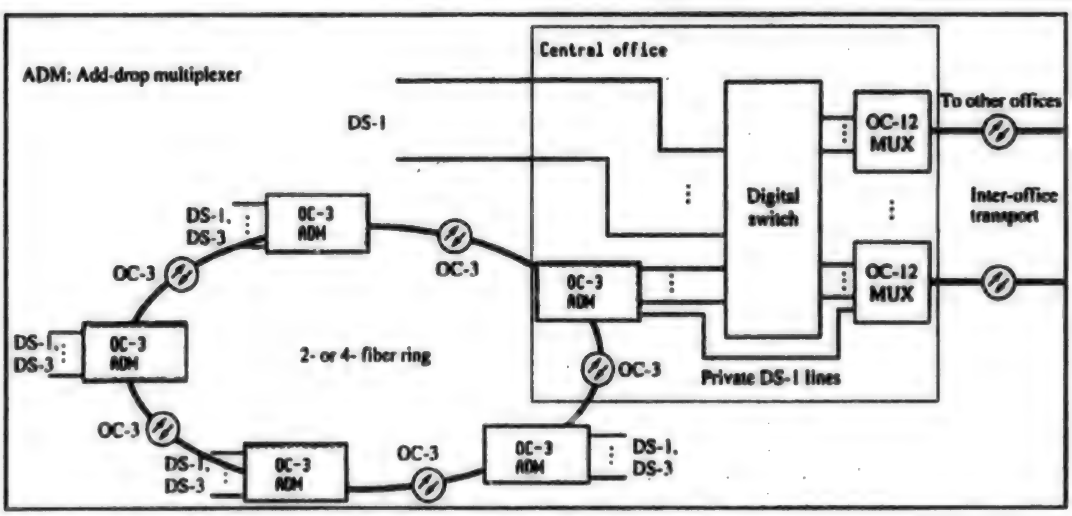

Figure 4. Self-Healing Ring Application

Equipment Features

Table 1 shows the main specifications of the OC-3 MUX/ADM. The OC-3 MUX/ADM is designed for flexible accommodation of a variety of lower order interfaces, and a full range of functionality, from a basic terminal multiplexer to an add/drop multiplexer in a self-healing architecture.

Table 1. Main Specifications

Item		Specification	Remarks
Physical structure		—Frame: Universal self-support rack (584mm (23 inch) EIA rack) or overhead-supported rack (584mm (23 inch) rack) —Shelf: 216mm (85 inch) H x 541mm (21.3 inch) W x 305mm (12 inch) D —Convection cooling	
System application		—Linear add/drop —2-fiber UPSR —2- or 4-fiber BLSR —Terminal —Hub	
Accommodation of lines		—DS 1:84 lines or —DS 3: 3 lines or	
Low-speed interface	Type	—DS 1 (1.544 Mbit/s, asynchronous) —DS 3 (44.736 Mbit/s, asynchronous)	
	Circuit card	—4 DS 1/small card —1 DS 3/small card	
	Signal characteristics	—DS 1: ANSI TI. 102 —DS 3: ANSI TI. 102	
	Transmission distance	—DS 1: 200 m (655 ft) —DS 3: 137 m (450 ft)	Distance to DSXN
High-speed interface	Type	—OC-3 (155.52 Mbit/s)	
	Circuit card	—1 OC-3/card	
	Fiber	—Single mode 1310 nm zero dispersion fiber	
	Signal characteristics	—TR-NWT-253, Issue 2	
	Transmission distance*	—Short reach: 2 km —Intermediate reach: 15 km —Long reach: 40 km	
Clock interface		—Receive clock: 1.544 MHz —Transmit clock: 1.544 MHz	

*Distances are nominal and for classification only.

EIA: Electronic Industries Association

UPSR: Unidirectional path switched ring

BLSR: Bi-directional line switched ring

DSXN: Digital signal cross-connect level N

The OC-3 MUX/ADM shelf is shown in Fig. 5, and can be mounted in a standard EIA 584mm (23 inch) bay which is compliant with the network element building system (NEBS) standardized by Bellcore. The basic dimensions of the shelf are 541mm (21.3 inch) wide x 305mm (12 inch) deep x 216mm (8.5 inch) high. A heat baffle is provided for convection cooling.

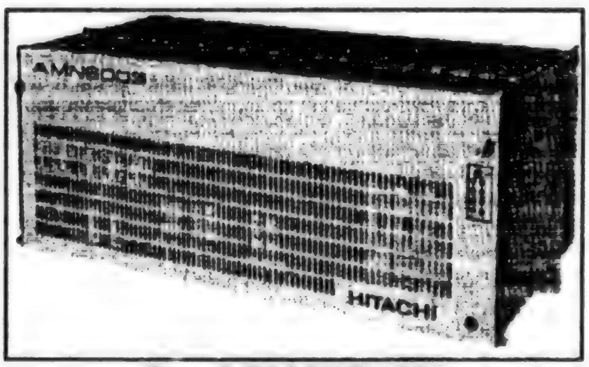

Figure 5. OC-3 MUX/ADM

The OC-3 MUX/ADM has the advantages of the next-generation SONET equipment. The first advantage is multiple self-healing topologies. The OC-3 MUX/ADM supports three self-healing rings, that is, a 2-fiber unidirectional path switched ring (UPSR), a 2-fiber and a 4-fiber bidirectional line switched ring (BLSR). The ring architecture is software reconfigurable. BLSR is quite

economical compared to the UPSR especially in inter-office applications because it allows reuse of bandwidth. So, OC-3 MUX/ADM is well-suited for application with inter-office networks as well as access networks. The second advantage is complete TSI capability, which allows cross-connection as VT-1.5 or STS-1 level across the entire STS-3. Because of this functionality, the OC-3 MUX/ADM can support DS-1 and DS-3 cross-connection, hairpin connection of VT-1.5 level, add/drop, continue, broadcast, and so on. The above two features realize various system configurations from a single shelf by software provisioning only.

Conclusion

This report has given an overview of Hitachi's OC-3 MUX/ADM, which has been developed as next-generation SONET equipment.

The major features of this equipment are as follows:

(1) Flexible application to traditional and advanced networks

The OC-3 MUX/ADM supports multiple self-healing ring topologies (2-fiber UPSR, 2-fiber BLSR, and 4-fiber BLSR) which are software reconfigurable. Therefore, it allows installation of cost-effective networks not only just access networks, but inter-office networks as well.

(2) Forward looking architecture

This equipment accommodates various low-speed interfaces in the same slot of the shelf. DS-1 and DS-3 are now supported as low-speed interfaces, and OC-1, STS-1 (51.84 Mbit/s) and other new interfaces will be applicable as low-speed interfaces in the future. Therefore, it achieves smooth transition to a multi-service network. The surveillance and control part of the equipment is designed for easy migration to advanced OAM&P. It has a craft interface, OS interface and LAN interface. These interfaces are now TL 1, and will be able to evolve into CMISE in the future.

High-Speed Multimedia Backbone LAN Applications

43070117F Tokyo HITACHI REVIEW in English Apr 94 pp 67-70

[Article by Masato Hirai and Isao Takanishi, Office Systems Division, Hitachi, Ltd.; and Toshihiko Ogura, Systems Development Laboratory, Hitachi, Ltd.]

[FBIS Transcribed Text]

Abstract

The Super LAN -600 is a high-speed multimedia backbone network which integrates data, voice, and video media, and which provides long distance (up to 40 km) transmission using optical fiber cables with a high transmission rate of 622.08 Mbit/s. Supporting video, voice, telephone, and data communication local area network (LAN) interfaces, it allows the construction of a multimedia network which meets a wide spectrum of business requirements and which fits various environments. Examples of its application to the manufacturing industry include a system configuration which combines access to design/manufacturing databases, transmission of computer-generated video images, and transmission of telephone conversations in an integrated manner. Another example, a public utility (such as electricity, water supply and sewage) application, integrates remote monitoring and control and telephony into a data communication LAN.

Introduction

In recent years, demand has been increasing for handling information generated or entered in a variety of forms within a premises, such as voice and video images, in addition to conventional data. Two problems have been slowing down the move to meet such demand. First, each form of information has required its own communication equipment. Second, while LAN speed has increased to sustain increases in amount of data transmitted within a premises, transmission rates between separate sites have not kept pace with LAN speed. To solve these problems, Hitachi has developed a high-speed multimedia backbone LAN called the Super LAN Σ-600 (Fig. 1). The Σ-600 was brought on the market in September 1990.

This paper describes applications of the Σ-600.

Σ-600 System Outline

Table 1 lists the major specifications of the Σ-600. The Σ-600 conforms, in internal frame structure and transmission rate (622.08 Mbit/s), to the synchronous digital hierarchy (SDH) standard of the ITU-T. It uses 1.3-μm single mode optical fiber as the transmission medium. Employing a dual-loop configuration, it supports "loop back" and "alternate loop" to enhance network availability. The maximum number of nodes connected is 127; the maximum node spacing can be selected from among 10, 25, and 40 km. The connection interfaces supported by the Σ-600 are the National Television System Committee (NTSC) interface for video transmission, TTC (Telecommunication Technology Committee, Japan) standard 2-Mbit/s interface, and the fiber distributed data interface (FDDI). Each node has four ports in any combination of these interfaces. In addition to the loop back and alternate loop functions, the Σ-600 supports a duplex configuration at the system level, to further improve system availability. The system is equipped with various network management functions, which focus on system status management and failure management.

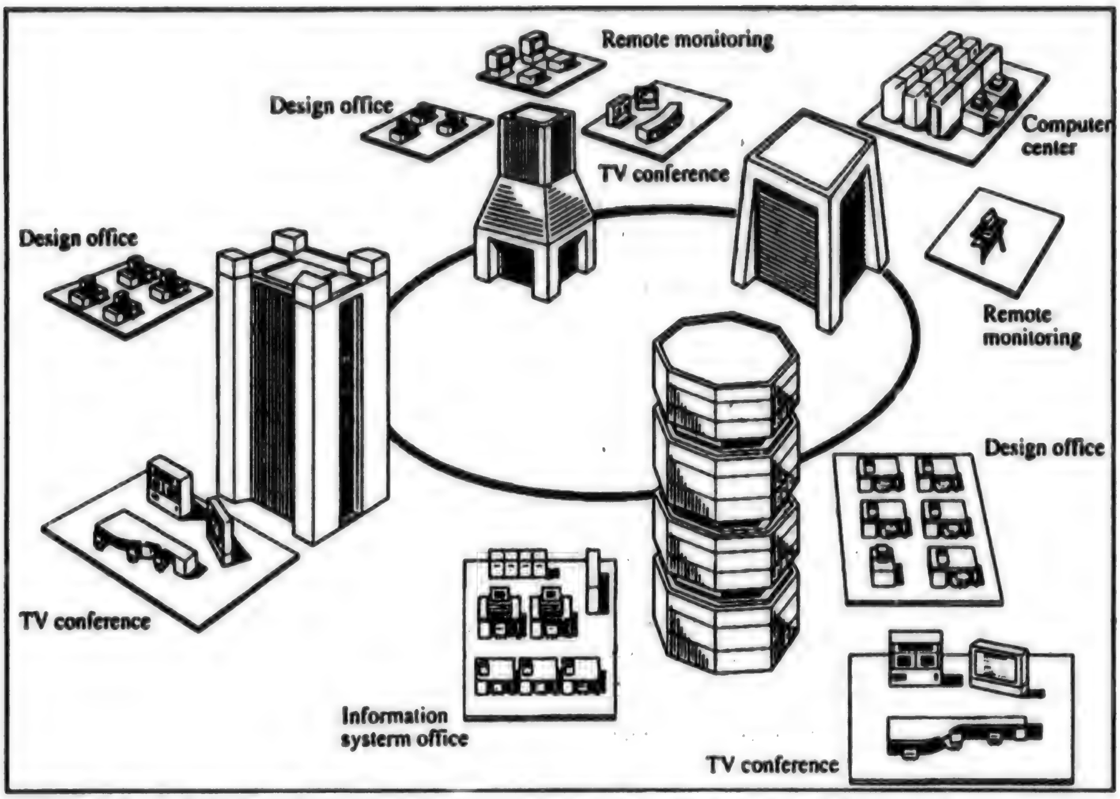

Figure 1. The Super LAN Σ-600 High-Speed Multimedia Backbone LAN. The Σ-600 allows the construction of a high-speed multimedia LAN with a transmission rate of 622.08 Mbit/s.

Table 1. Major Specifications of the Σ-600. The Σ-600 allows the construction of a large-scale multimedia LAN.

Transmission rate	622.08 Mbit/s
Transmission medium	1.3-µm single mode fiber (dual loop)
Maximum number of nodes	127
Maximum node spacing	10, 25, and 40 km (selectable)
Interfaces supported	NTSC video interface Time-division-multiplexing 2 Mbit/s (TTC standard) FDDI
RAS features	Dual loop (loop back and alternate loop) Duplex-configuration system
Network management	Status, configuration, and failure management
FDDI: Fiber distributed data interface	
TTC: Telecommunication Technology Committee, Japan	
NTSC: National Television System Committee	
RAS: Reliability, availability, and serviceability	

System Applications

Features

A variety of networks can be configured, taking advantage of the following features of the Σ-600:

- It makes the construction of a multimedia network easy by interconnecting LANs which carry different forms of information such as video images, voice and coded data.
- The node spacing limit of as long as 40 km significantly eases distance constraints in building a high-capacity (622.08 Mbit/s) network.

Table 2 lists examples of the Σ-600 applications.

Table 2. Applications of the Σ-600. The Σ-600 can be used in a variety of application fields.

Application field		Application	Industry
Research, development, design, manufacturing		Image-intensive database retrieval (drawings and design information) Display of computer-generated video images for visualization of simulation results	Manufacturing (automotive, electrical, and shipbuilding)
Monitor and control over wide area		Close monitoring by use of real-time video images Centralized remote control at a central control station Retrieval from a database such as maintenance drawings at the remote site	Utilities (electricity, water supply and sewage, railroad, gas transmission, and roads)
Office automation	Intra-building, Inter-building (intelligent building)	Expandable intra-building communication network —Floor LAN (integration of token-ring and CSMA/CD LANs) —Accommodates various types of transmission interfaces —Telephone network	All industries
	Remote connection (head-to-branch offices factory-to-factory)	FDDI connection between LANs with high-speed transmission (100 Mbit/s rate) TV conferencing to decrease the frequency of business trips Distributed PBX system Distributed PBX system	
Academic environment		Sharing system resources such as a supercomputer and a large-scale database Lecturing, presenting, and teaching by use of video images Display of computer-generated video images for visualization of simulation results	Laboratory, university
Plant control		Close monitoring by use of real-time video images Real-time process control	Chemical steel

PBX: Private branch exchange; CSMA/CD: Carrier sense multiple access with collision detection

Application Examples

(1) Application in a Manufacturing Company

The Σ-600 system allows tight interconnection of various departments of a company, such as research, design, manufacturing, quality assurance and general administration, spread out in a large premises or even spanning more than one site across a road, as illustrated in Fig. 2.

The research and design departments share development resources, such as a database server and a supercomputer. Researchers and engineers can view, on the video displays in their offices, the results of numerical analysis performed and visualized by the supercomputer, or they can design complex objects using a graphics CAD system which runs on personal computers or engineering workstations. The graphics database of manufacturing drawings can be retrieved at a high speed (100 Mbit/s) from anywhere in the design office and the manufacturing lines. A high-speed multimedia network is essential in building such a distributed and collaborative environment for development and manufacturing.

The Σ-600 system can also bring more value to the corporate office automation (OA), by linking production schedules to the order information held in the information system department, facilitating the generation of management information, and introducing electronic mail.

Combined with private branch exchanges (PBXs), the system can also handle voice, video images, and data, so that video conferencing and corporate broadcast services can be provided over the same network.

(2) Application in a Local Government

The Σ-600 can be used by a local government to remotely monitor and control roads and public utility facilities up to tens of kilometers away, or as part of the communication infrastructure for providing various services to both citizens and offices alike, as illustrated in Fig. 3. The Σ-600 system makes it possible to remotely monitor the water levels of rivers flowing over a wide area for flood prevention, or to monitor and control water supply and sewage facilities from a central station in real time. With on-site monitor cameras operated from a central control station, such a system allows quick detection of danger points, by providing clear, real-time pictures of river flow and pump operation.

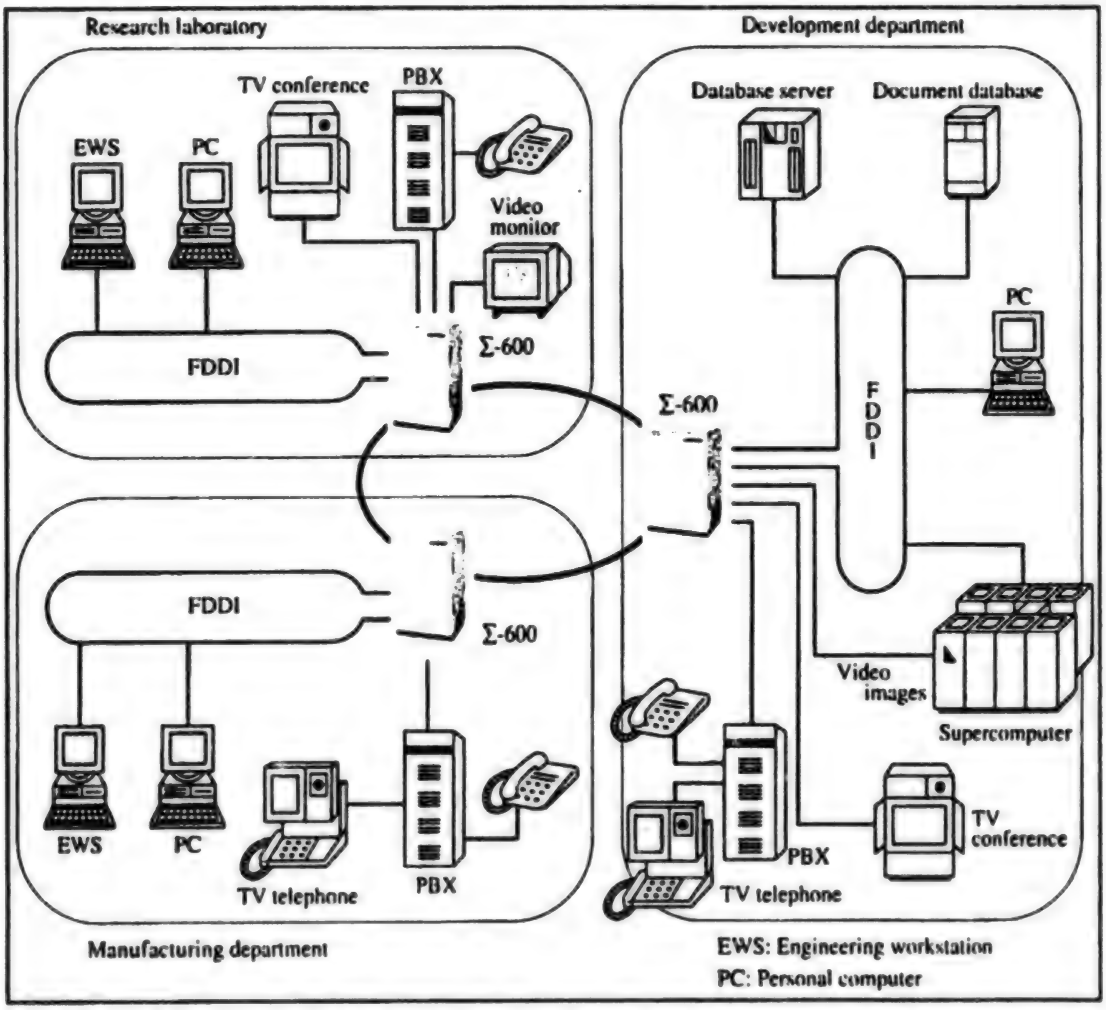

Figure 2. Example of Application in a Manufacturing Company. The integrated system enhances productivity by means of FDDI connections, which provide high-speed access to a shared database, viewing of video synthesized by a supercomputer, TV conferencing, and TV telephony.

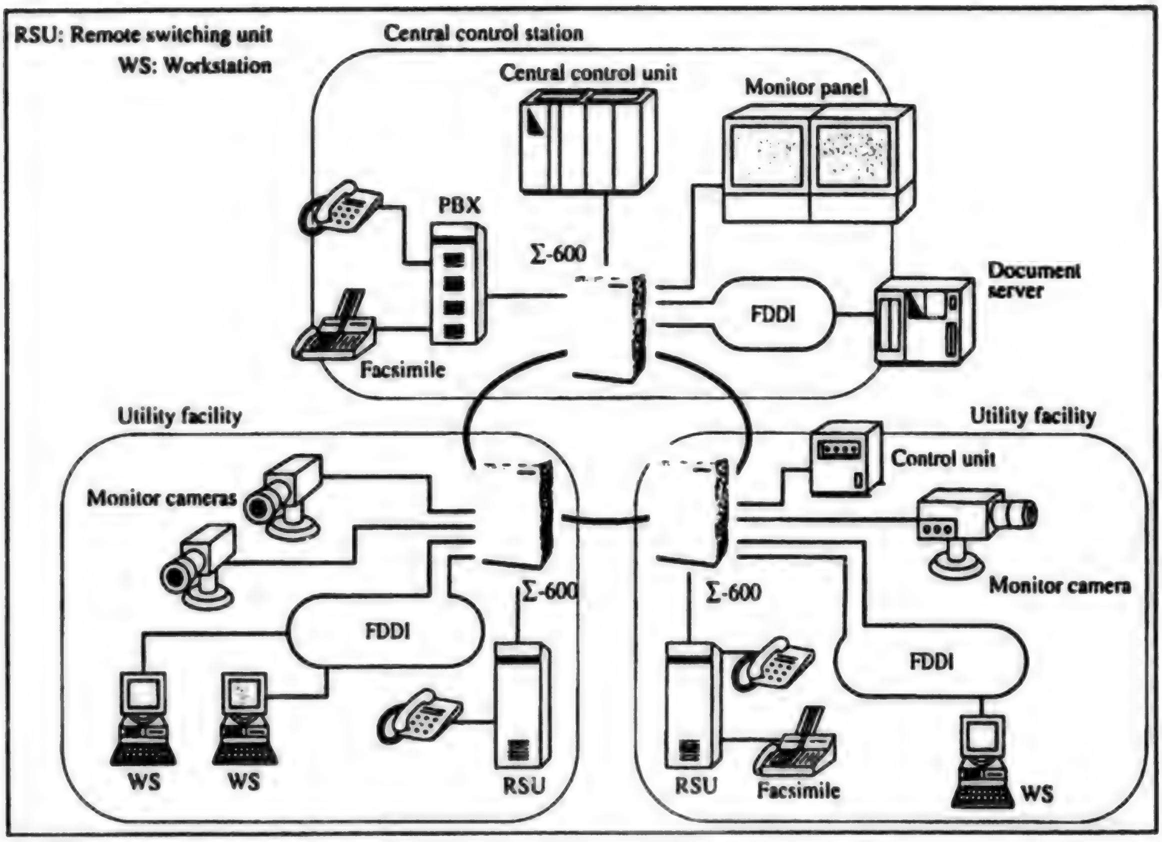

Figure 3. Example of Application in a Local Government. A sophisticated monitoring/control system can be built, which integrates remote monitoring and control of utilities, remote retrieval of maintenance documents and facsimiles/telephones.

The maintenance personnel can retrieve maintenance drawings and associated information from the document server in the control station through a workstation on site.

The Σ-600 system can also be used as a basis for enhancing services to citizens. Resident registers, for example, can be retrieved or updated easily from any branch of the city office. The use of electronic mail or video images would improve the speed and quality of public announcements.

On the Σ-600, it is also easy to construct a telephone/facsimile network by installing PBXs, remote switching units (RSUs) and multifunction telephones.

Future Perspective

Over the years to come, multimedia technology will make further inroads into human society, by integrating high-definition television into the computer network, supporting high-speed file transfer between computers, and incorporating data compression, which will significantly increase the number of communication channels accommodated on each network. The Σ-600 network will be indispensable in building such an advanced multimedia infrastructure.

Conclusions

Applications of the Super LAN Σ-600, Hitachi's multimedia high-speed backbone LAN, have been described. With significantly longer connections and a higher bandwidth than ordinary LANs, the Σ-600 meets a wide range of advanced systems requirements in terms of communication speed, geographical area of coverage, configuration and media supported.

References

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150-Mbit/s, 600-Mbit/s, and 2.4-Gbit/s Optical Interface Modules for SDH Transmission Systems

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[Article by Kiichi Yamashita, Kazuhide Harada, and Yasuhiro Yamada, Fiberoptics Division, Hitachi, Ltd.]

[FBIS Transcribed Text]

Abstract

Compact SDH (synchronous digital hierarchy) optical interface modules for STM-1 (synchronous transport module-1; 155.52 Mbit/s), STM-4 (622.08 Mbit/s) and STM-16 (2.48832 Gbit/s) transmission systems, based on ITU-T recommendations, have been developed using novel wideband monolithic integration and high-density packaging technologies for the transmitter and receiver circuits. In the monolithic integration, 2-μm and 1-μm Si-bipolar processes were adopted to miniaturize the STM-1 and STM-4 modules. For the STM-16 module, which operates at high speed, 0.8-μm GaAs MESFET device technology with its inherent wideband performance was applied. Also, high-density packaging technology minimizes receiver sensitivity degradation due to crosstalk noise. As a result, both the STM-1 modules for intra-office and inter-office system applications, in particular, were incorporated into 10-cc and 20-cc volumes, which are, respectively, one-tenth and one-fifth the volume of existing version 1 modules for both applications implemented at Hitachi, Ltd.

Introduction

In public telecommunication networks, synchronous digital hierarchy (SDH) was standardized by the ITU-T, in 1988, toward the construction of Broadband Integrated Services Digital Network (B-ISDN).[1] Since then, much of the SDH optical transmission equipment operating at bit rates of 51.84 Mbit/s to 2.48832 Gbit/s has been successfully introduced into intra-office and inter-office transmission systems based on ITU-T recommendations.

As shown in Fig. 1, the standardized transmission bit rates are classified into three categories, that is, synchronous transport module-1 (STM-1: 155.52 Mbit/s), STM-4 (622.08 Mbit/s) and STM-16 (2.48832 Gbit/s). Under such circumstances, advantages of standardized optical interfaces will be found in packaging density, power dissipation, cost and reliability. Because of the growing installation of transmission systems, more and more strict requirements are being set for optical interface modules with respect to size, reliability, power dissipation and cost. Furthermore, in long-haul transmission lines such as in inter-office networks, high receiver sensitivity is required for the modules. In addition, a clock recovery function is essential for constructing synchronous digital transmission systems.

To meet these requirements, monolithic integration for drastically reducing the number of transmitter and receiver circuit components, and the development of high-density packaging technology for suppressing crosstalk noise between various signals are major subjects. This paper describes the design, fabrication and characteristics of the optical interface modules for the STM-1, STM-4 and STM-16 transmission systems developed by Hitachi, Ltd.

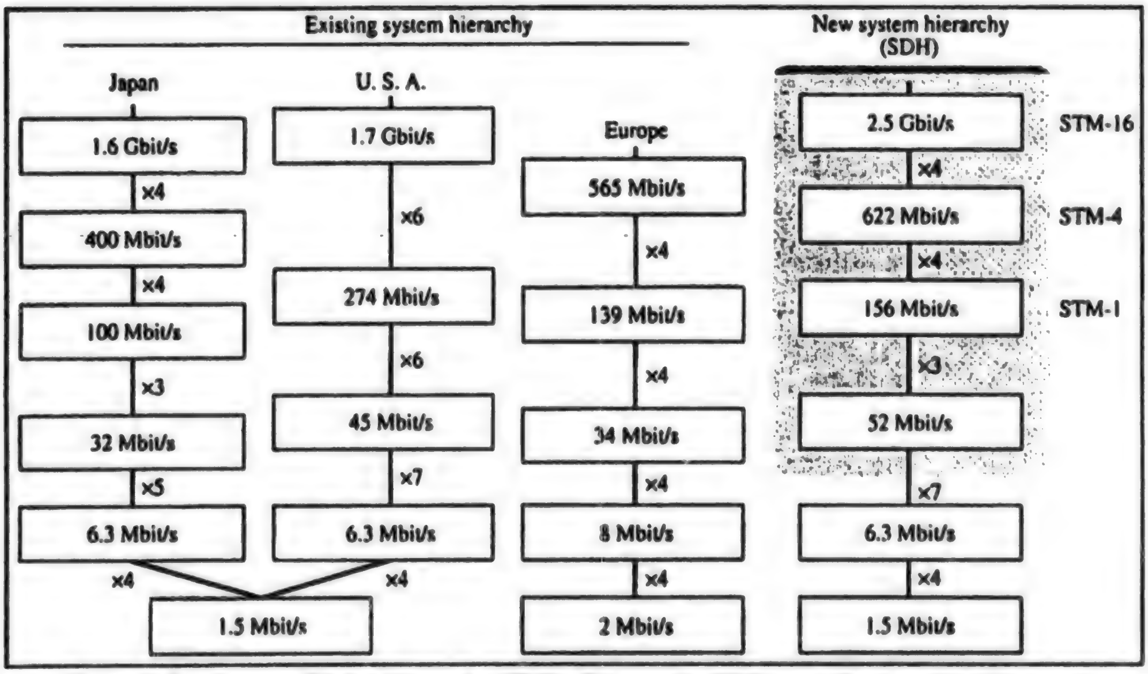

Figure 1. Synchronous Digital Hierarchy (SDH). Bit rates for SDH are defined as 156 Mbit/s x N.

SDH Optical Interface Specifications and Module Design

Optical Interface Specifications

Design targets are compact optical interface modules based on ITU-T recommendations with respect to intra-office, short-haul and long-haul inter-office transmission systems operating at bit rates from 155.52 Mbit/s to 2.48832 Gbit/s, respectively, as listed in Table 1. The recommendations determine in detail SDH optical interface specifications for optical source, transmission wavelength, media and characteristics at each bit rate and non-repeater span. In the non-repeater span of less than 40 km, Fabry-Perot laser diodes (FP-LDs) with a wavelength of 1.3 μm are adopted as optical sources. Also 1.3-μm zero-dispersion shifted fiber is used as the transmission medium. For transmission systems with over 40-km spans, distributed feedback laser diodes (DFB-LDs) and 1.55-μm zero-dispersion shifted fiber are used to minimize dispersion penalty for the receiver sensitivity due to LD wavelength fluctuation and fiber chromatic dispersion.

Table 1. SDH Optical Interface Specifications. Transmitted and received optical power is defined for the given bit rates and non-repeater spans

Applications			Intra-office	Inter-office				
				Short-haul		Long-haul		
Wavelength (nm)			1310	1550	1310	1550		
Transmission line			SMF	SMF	SMF	SMF	SMF	DSF
Span (km)			≤2	to 15		40	to 60	
Transmit/ received power (dBm) $P_e = 10^{-11}$	STM-1 (156 Mbit/s)	TX	-8 to -15	-8 to -15		0 to -5		
		RX	-8 to -23	-8 to -28		-10 to -34		
	STM-4 (622 Mbit/s)	TX	-8 to -15	-8 to -15		+2 to -3		
		RX	-8 to -23	-8 to -28				
	STM-16 (2.5 Gbit/s)	TX	-3 to -10	0 to -5			+1 to -4	0 to -5
		RX	-3 to -18	0 to -18		-10 to -26	-9 to -26	- 10 to -26

SMF: Single mode fiber; DSF: Dispersion shifted fiber; TX, RX: Transmitter, receiver

Module Design

Minimizing the number of module types is important from the standpoint of cost effectiveness because of the expected increase in production volume. Therefore, the optical interfaces in these systems are covered by eight types of modules. An optical transceiver type module, in which transmitter and receiver are integrated into a single package, significantly contributes to the incorporation of a compact optical interface module. Therefore, this design concept is adopted for the STM-1 module. A functional block diagram of the optical transmitter and receiver modules is shown in Fig. 2. These modules consist of an optical source, detector, transmitter, and receiver circuits with a clock recovery function, as well as shutdown and alarm output circuits for optical received and emitted signals.

As optical devices, a combination of FP-LD and InGaAs photodiode (PD) is adopted for short-haul system applications, taking into account module cost and performance. Also the combination of DFB-LDs and Ge/InGaAs avalanche photodiodes (APDs) is chosen as the optical devices for long-haul transmission system applications. To reduce the number of circuit components drastically, monolithic integration of transmitter and receiver circuits, that is, the LD driver, variable-gain amplifier and retiming circuit, is carried out using Si-bipolar and GaAs MESFET IC technologies, resulting in compact size, high reliability and low cost. Concerning clock recovery, a surface acoustic wave (SAW) filter is chosen for low-jitter clock-extraction and operation stability. A compact SAW filter capable of surface-mounting on a printed circuit board was developed for the STM-1 modules.

Module Miniaturization Technologies

Monolithic Integration Technology

Difficulties in the monolithic integration of optical transmitter and receiver circuits relate to bit rates and device performance. Therefore, IC process choice and chip partitioning are important. The IC process and chip partitioning for STM-1, STM-4, and STM-16 modules are shown in Fig. 2 and Table 2, respectively. For STM-1 and STM-4 modules, Si-bipolar processes with emitter widths of 2 μm and 1 μm, respectively, were adopted, which have a capability of integrating main signal-processing circuits and control/alarm circuits on the same chip. To realize high speed operation, a 0.8-μm GaAs metal semiconductor field effect transistor (MESFET) process was also applied to the monolithic integration of STM-16 modules. Moreover, a pre-amplifier in STM-1 module was designed using the approach for hybrid integrated circuits with a low-noise microwave GaAs FET in order to achieve high receiver sensitivity.

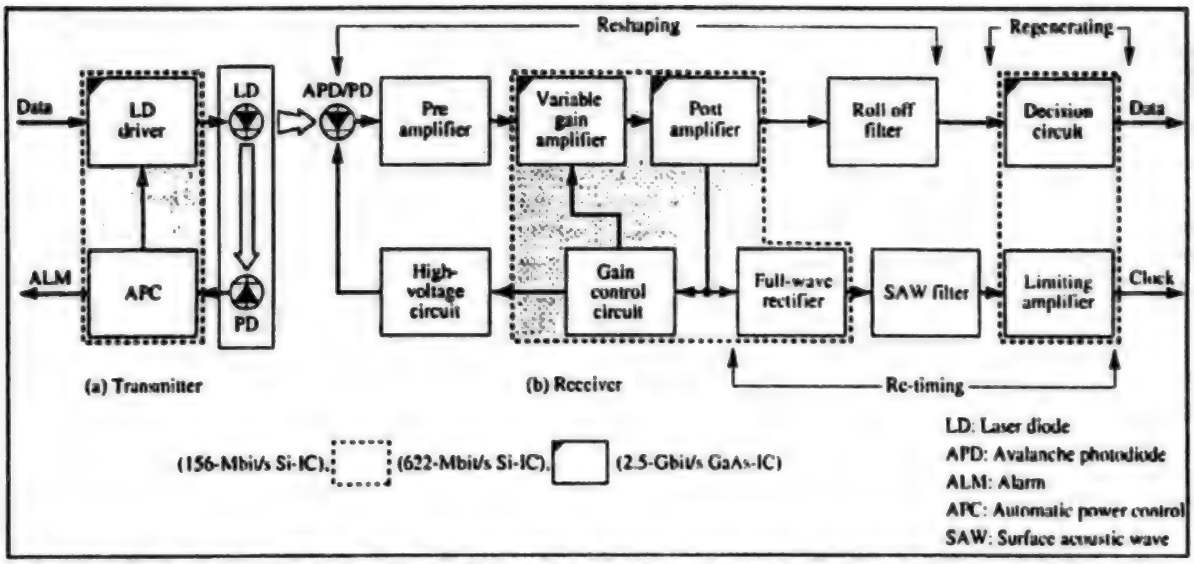

Figure 2. Basic Configuration of the Optical Interface Module and IC Chip Partitioning Plan. Main transmitter and receiver circuits for the STM-1/STM-4 modules and STM-16 modules are monolithically integrated using the Si-bipolar IC process and GaAs MESFET IC process, respectively.

Table 2. IC Classification for Optical Interface Modules

Bit rate (bit/s)	IC process (L_E/$L_g$reset)	ICs						
		LD driver	Pre-amplifier	Variable gain amplifier	Post amplifier	Full-wave rectifier	Decision circuit	Limiting amplifier
156M	(2-μm) Si-bipolar	X	Hybrid		X		X	
622M	(1-μm) Si-bipolar		X	X			X	
2.5G	(0.8-μm) GaAs-MESFET	X	X	X	X	X	X	X

L_E: Emitter width; L_g: Gate width

Based on such considerations, the transmitter and receiver circuits of the STM-1 and STM-4 modules were partitioned into three and four chips, respectively. Chip partitioning of the STM-16 module was determined taking into account the integration feasibility of main signal processing and control/alarm circuits on the same chip using the GaAs MESFET process. As this process produces large device parameter dispersion compared with Si-bipolar process, the integration of main signal-processing and control/alarm circuits on the same chip is very difficult and power dissipation is large. Accordingly, automatic power control (APC) and automatic gain control (AGC) circuits were implemented with ICs. As a result, the STM-16 module consists of seven chips.

High-Density Packaging Technology

In this section, technology for high-density packaging of STM-1 modules is described, because the miniaturization is most advanced in the STM-1 modules, among all the SDH modules developed at Hitachi, Ltd.

Although a transceiver type module has the advantage of increasing the packaging density of the transmission equipment, this type of module is likely to introduce problems such as sensitivity degradation and receiver operation instability. The problems are caused by crosstalk noise with various interference levels, because a large transmitter signal can leak to a receiver operating at a small signal level. Requirements of more compact modules will increase this problem, and the minimum package size may be limited in order to suppress the receiver sensitivity degradation due to crosstalk noise. Design of a transceiver module that minimizes crosstalk noise is the key issue.

The correlation between the causes of crosstalk noise, and approaches to solving these problems are summarized in Fig. 3. Crosstalk is mainly caused by crossed or proximally parallel paths of signal lines, and high impedance power supply and ground lines. Also free-space radiation has to be considered as another cause of crosstalk. Separation of the wiring according to the signal level, reduction of the line impedance, minimization of

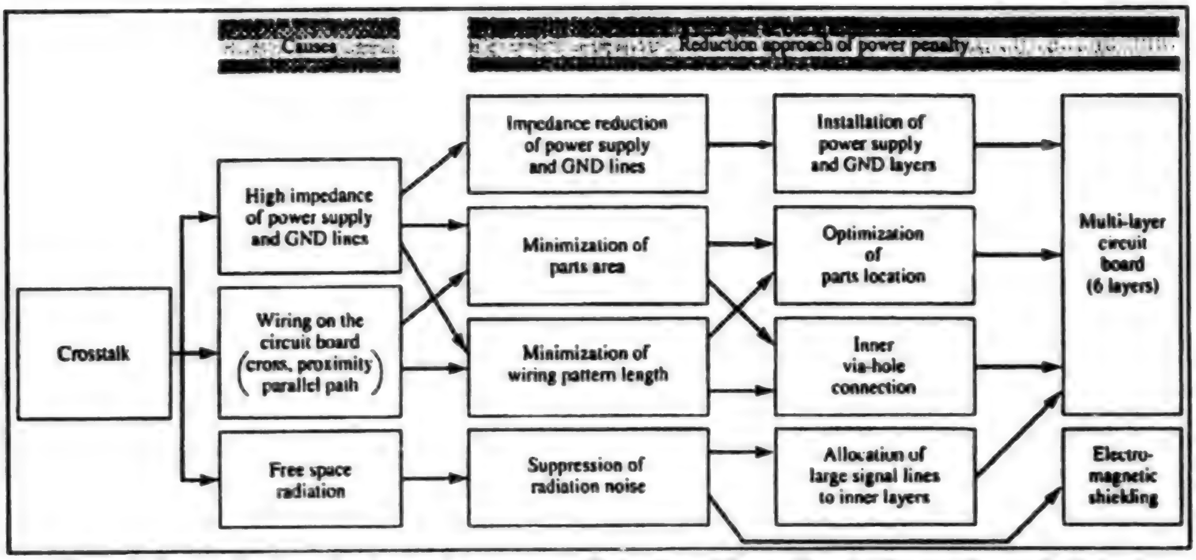

Figure 3. Crosstalk Classification and Approach to Reduction of Power Penalty Due to Crosstalk Noise in Miniaturization of STM-1 Optical Interface Modules.

wiring length and sufficient shielding are key steps to solving these problems. As a part of the solution, a six-layer alumina ceramic substrate with inner via-holes was selected for the module's printed circuit board. Ground and power supply lines were divided into different layers to separate lines of different signal power levels. One layer was assigned to the transmitter I/O interface signal lines and two layers were assigned to the ground line. The former was sandwiched between the ground layers to shield from leakage of the LD driver current pulse and digital input signals. The transmitter and receiver circuits were mounted on opposite sides of the substrate with the ground layers located between them. The receiver front-end, which has high input impedance, was electromagnetically shielded in order to avoid the degradation of receiver sensitivity induced by leakage of the LD driver current pulse. Observed degradation of receiver sensitivity caused by crosstalk noise was confirmed to be less than 0.5 dB.

Two types of complete module packages, shown in Fig. 4, were fabricated by developing the technologies mentioned above, one for intra-office system application and the other for inter-office system application. The module package sizes are L: 50mm x W: 25mm x H: 8mm (volume: 10 cc) for the intra-office system application and L: 81mm x W: 31mm x H: 8mm (volume: 20 cc) for the inter-office system application. Table 3 shows a history of the development of optical interface modules for inter-office system application at Hitachi, Ltd. The V3 module can be reduced into one-tenth the size and one-half the power dissipation of the existing V1 module. Similar results (one-fifteenth the size and one-half the power dissipation) were achieved for the V3 module for intra-office system application.

Table 3. Deployment of STM-1 Optical Interface Modules for Intra-Office System Applications

Version (year)		V1 (1989)	V2 (1991)	V3 (1992)
Structure		TX/RX separate type	TX/RX transceiver type	Transceiver type same size for 52M, 156M
		TX/RX separate substrate	TX/RS separate substrate	Single substrate both side mounting
Volume		110 cc	40 cc	10 cc
TX/RX IC	Amount	4	3	3
	PKG	40 pin LCC 20 pin LCC	40 pin QFP 20 pin LCC	20 pin LCC
Density (each IC) (Relative ratio)		1	1.24	1.72
Number of components (relative ratio)		1	0.65	0.41
SAW filter		0.6 cc	0.5 cc	0.2 cc
Power dissipation		2.6 W	2.0 W	1.3 W

TX: Transmitter; RX: Receiver; LCC: Leadless chip carrier; QFP: Quadrature flat package; PKG: Package

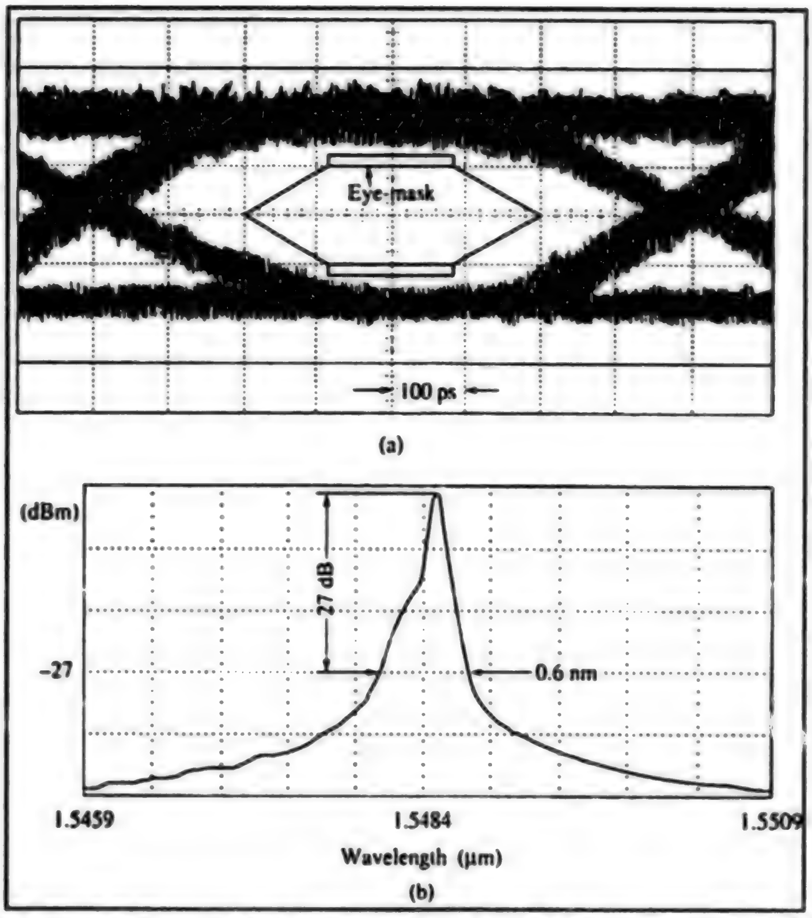

Figure 4. Optical Output Characteristics of the TRM 7934 STM-16 Transmitter module. (a) Optical output eye pattern, (b) LD spectrum for a 2^{23}-1 bit length pseudorandom nonreturn to zero transmission code.

Module Characteristics and Applications

Characteristics

Table 4 shows the product line-up and characteristics of STM-1, STM-4 and STM-16 modules developed at Hitachi, Ltd.

Table 4. Major Characteristics of SDH Optical Interface Modules Developed at Hitachi, Ltd. The STM-1 modules are implemented as compact transceiver-type modules with volumes of 10 cc and 20 cc for intra-office and inter-office system applications, respectively.

Item	Unit	STM-1		STM-4				STM-16	
Transmission speed	Mbit/s	155.52		622.08				2488.32	
Transmission length	km	0.4	40	2	15	40	80	40	80
Wavelength	nm	1310		1310			1550	1310	1550
Structure	—	Transceiver type		TX, RX; separate type				TX, RS: separate type	
Volume (TX/RX)	cc	10	20	18/24	18/110	49/110		133/222	

Table 4. Major Characteristics of SDH Optical Interface Modules Developed at Hitachi, Ltd. The STM-1 modules are implemented as compact transceiver-type modules with volumes of 10 cc and 20 cc for intra-office and inter-office system applications, respectively. (Continued)

Item		Unit	STM-1		STM-4				STM-16	
Transmitter module	Optical output	dBm	-10 to -13	-4 to -1	-12 to -10		-1.0 to +1.0		0 to -3	+1 to -2
	Optical source	—	FP-LD		FP-LD		DFB-LD	DFB-LD	DFB-LD	MQW DFB-LD
	Model	—	SDC 5466	SDC 5467	TRM 5714	TRM 5715	TRM 5712/ 5732	TRM 7732	TRM 5934	TRM 7934
Receiver module	Maximum received power	dBm	-4.5	-6.5	-4.9	-6.3	-12.4	-12.4	-8.2	-8.0
	Minimum received power	dBm	-32.5	-40.5	-28.1	-37.6	-39.0	-39.0	-32.0	-31.0
	Optical detector	—	InGaAs-PD	Ge-APD	InGaAs-PD	InGaAs-APD	InGaAs-APD		InGaAs-APD	
	Model	—	TRV 5466	TRV 5467	RCV 5703	RCV 5702	RCV 5732		RCV 5931	
Power consumption (TX/RX)		W	1.3	1.5	1.2/1.1	1.2/2.7	3.3/2.7		3.3/4.6	

FP-LD: Fabry-Perot laser diode; DFB-LD: Distributed feedback laser diode; MQW: Multi quantum well; APD: Avalanche photodiode; PD: Photodiode

(1) Structure and volume: Module structures are determined from the viewpoint of bit rate, power dissipation, crosstalk noise between transmitter and receiver and so forth. For bit rates of over 622.08 Mbit/s, power dissipation increases because high-speed and broadband ICs are required. Also, it is difficult to integrate the transmitter and receiver in a single package because crosstalk noise between the transmitter and receiver increases in proportion to bit rate. Therefore, STM-4 and STM-16 modules comprise separate transmitter and receiver packages. On the other hand, at bit rates of less than 155.52 Mbit/s, STM-1 modules were incorporated in transceiver forms, because the power dissipation and crosstalk noise can be reduced, as described in the previous section. Volume ratios of the STM-1, STM-4, and STM-16 modules for a non-repeater span of over 40 km are 1, 8, and 18, respectively.

(2) Characteristics: Fig. 4 shows an optical output eye-pattern and optical spectrum performance of transmitter modules for STM-16. The eye pattern was observed through a 4th-order Bessel filter and matches the eye-mask defined in the ITU-T standard. Optical spectrum width is 0.6 nm (27-dB down from peak power). Fig. 5 shows bit error rate curves. Power penalty in the STM-16 modules was 0.2 dB for a 1.3-μm wavelength and 40-km non-repeater span, and 1.4 dB for a 1.5-μm wavelength and 70-km non-repeater span, respectively. Power penalties in the STM-1 and STM-4 modules were negligibly small in the non-repeater span of 40 km. In all of the modules, the deviations of optical output power owing to the temperature variation from 0 to 65°C were less than 0.3 dB. Optical output power of the developed modules is shown in Table 4. The values meet the CCITT standard shown in Table 1.

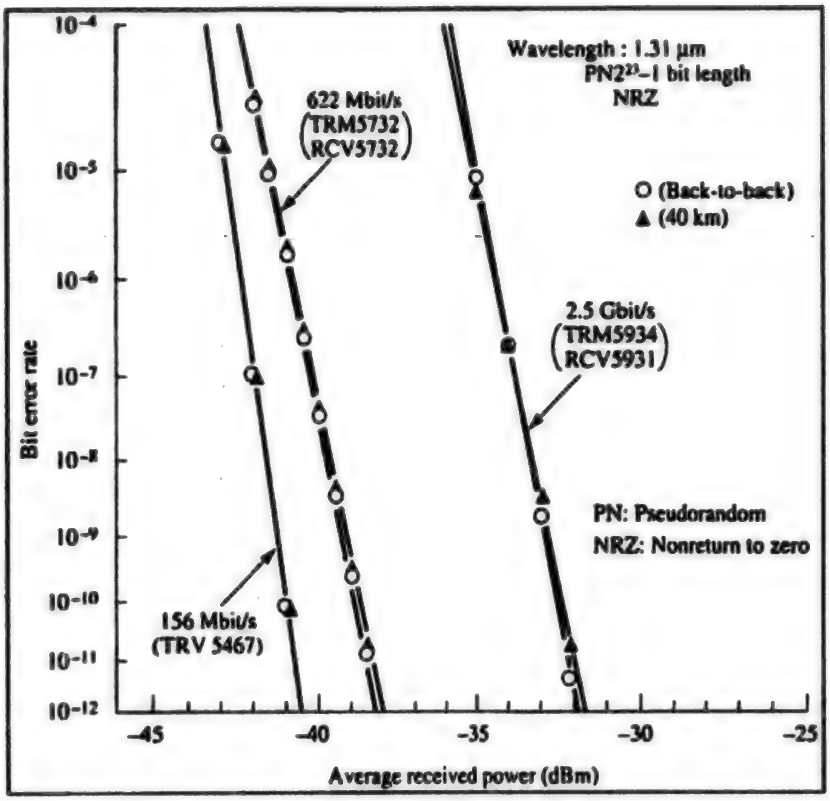

Figure 5. Bit Error Rate Characteristics of SDH Optical Interface Modules. Power penalties are less than 0.2 dB in 40-km transmission experiment.

Applications

Applications of the implemented optical interface modules are summarized in Fig. 6. The figure shows the first such SDH transmission systems in the world.[2] These intra-office and inter-office systems can flexibly and effectively use and manage various high-quality communication networks corresponding to the deployment of multi-media information exchange. In Fig. 1, terminating and converting modules which multiply existing low bit rate signals to signals with bit rates of 51.84 Mbit/s and/or 155.52 Mbit/s, cross connect modules which insert multiplied signals into each circuit, and fiber transport modules which multiply 51.84 Mbit/s to 622.08 Mbit/s or 2.48832 Gbit/s are installed in each transmission node. The implemented modules are applied to the optical interfaces of systems based on the requirements of users and can span intra-office systems to trun'· line systems.

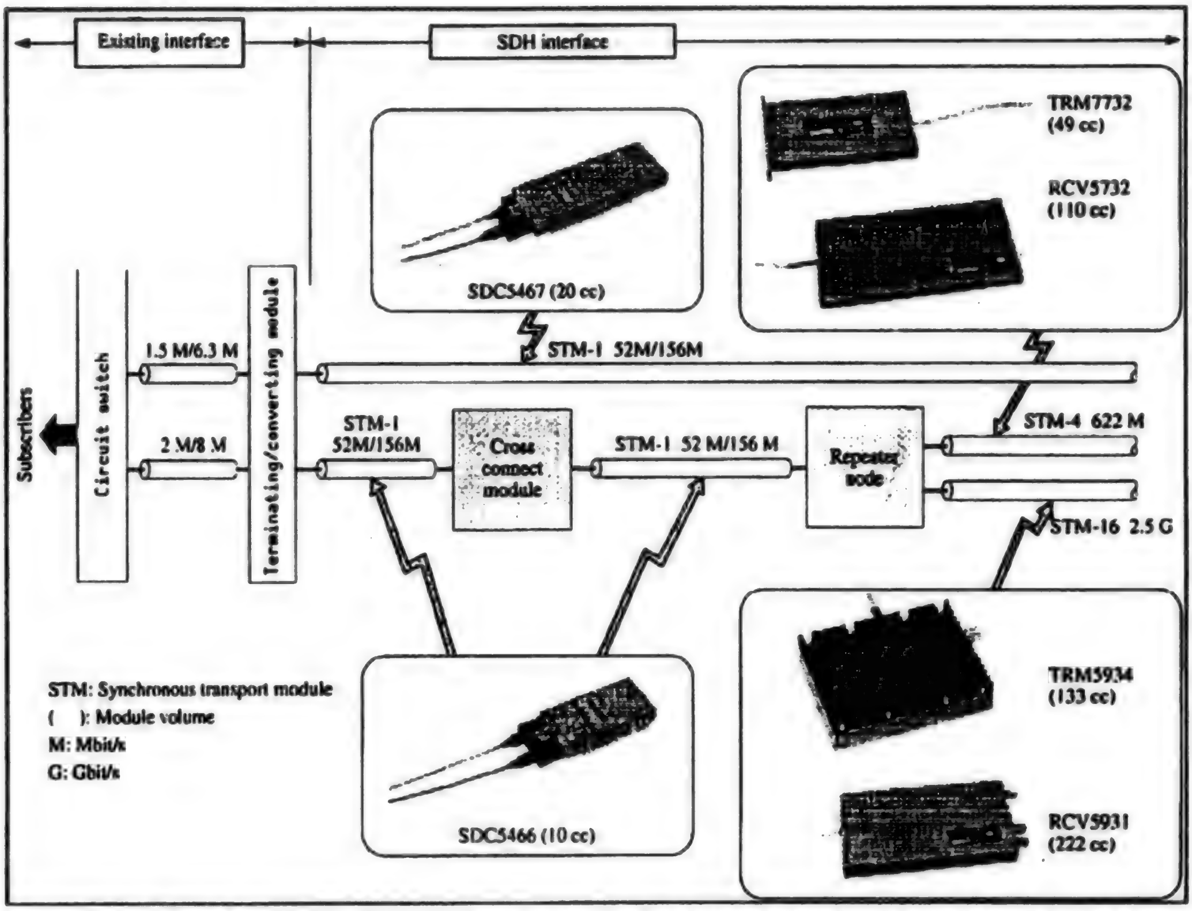

Figure 6. Basic SDH System Architecture and Optical Interface Module Applications. Optical interface modules are applicable to STM-1 (155.52 Mbit/s), STM-4 (622.08 Mbit/s), and STM-16 (2.48832 Gbit/s) systems.

Conclusion

Compact optical interface modules for STM-1, STM-4 and STM-16 transmission systems have been developed. In particular, the volumes of implemented STM-1 modules achieved 10 cc for intra-office system applications and 20 cc for inter-office system applications, respectively, which are the smallest of any modules developed at Hitachi, Ltd. They are less than one-tenth and one-fifth the volume of existing version 1 modules for both applications, respectively. The successful development of the optical interface modules was achieved using the following technologies:

(1) 2-μm/1-μm Si-bipolar and 0.8-μm GaAs MESFET IC technologies for monolithic integration of the STM-1/STM-4 and STM-16 modules, respectively.

(2) High density packaging and printed board patterning technologies for minimizing crosstalk noise utilizing a multilayer alumina ceramic or glass epoxy substrate shield mount configuration.

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Optical Interconnection Modules Utilizing Fiber-Optic Parallel Transmission To Enhance Information Throughput

43070117H Tokyo HITACHI REVIEW in English Apr 94 pp 79-82

[Article by Yoshihiro Motegi and Atsushi Takai, Fiberoptics Division, Hitachi, Ltd.]

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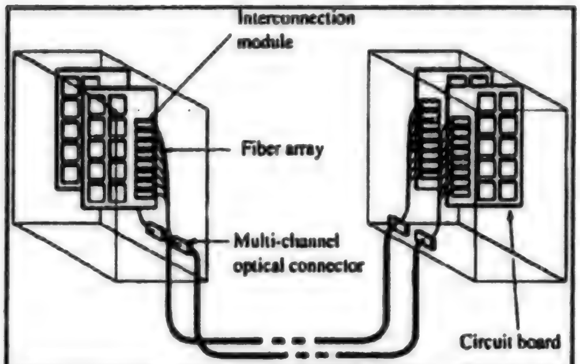
Abstract

Optical interconnection, which uses multi-channel optical fiber transmission, is one of the promising candidates for solving the wire bottleneck problem and enhancing information throughput in large-capacity switching systems and high-speed computers. This paper describes the newly developed 200-Mbit/s 8-channel parallel optical interconnection modules that are assembled with 8-channel low threshold laser diode (LD) arrays, photodiode (PD) arrays, and driver/receiver array ICs in small packages which are coupled with a single-mode fiber array.

Introduction

Recently there has been a tremendous effort to create high-speed, high-density interconnections for advanced high performance systems, such as large-capacity switching systems and high-speed computers. It has been predicted that electrical interconnections using conventional coaxial cables will limit the performance, size and total weight of systems. The optical subsystem interconnection based on synchronous parallel optical-fiber transmission is one of the most promising candidates for meeting the demand for enhanced information throughput of these systems because optical fiber has many advantages for use in interconnections such as wide bandwidth, low loss, low crosstalk, light weight, small cross-section and immunity from electromagnetic-interference (EMI).[1-4]

Fig. 1 shows a schematic view of the subsystem and the system requirements for optical interconnection which allows high throughput and high density.



System requirements
1. Small skew synchronous parallel transmission
2. Error free unformatted (uncoded) data transfer
3. Small size and low power consumption
4. Low cost
5. High reliability

Figure 1. Schematic View of the Subsystem and System Requirements

From a system viewpoint, most of the experimental work has involved light emitting diode (LED) arrays and multi-mode (MMF) fiber arrays.[(3),(4)] The moderate temperature dependence of LEDs and the less stringent optical alignment required by MMFs have made those arrays preferable for component design.

In our work, the LD arrays and single-mode fiber (SMF) arrays system were selected because the skew, or difference in the transmission delay time, in the fiber arrays, cannot be ignored. In addition, the system has an error-free unformatted data transmission capability.

In this paper, the newly developed compact 200-Mbit/s 8-channel parallel optical interconnection module using LD arrays and SMF arrays is described. The module performance demonstrates the suitability of the optical interconnections.

Design

Fig. 2 shows a photograph of the parallel interconnection modules developed in this work. The package size of both transmitter and receiver is 9mm W x 14mm L x 6mm H (0.8 cc). Each package has a pig-tailed fiber array with an 8-channel optical connector and 11 electrical pins; eight for ECL data input or output, two for ground connection and one for -5.2V power supply.

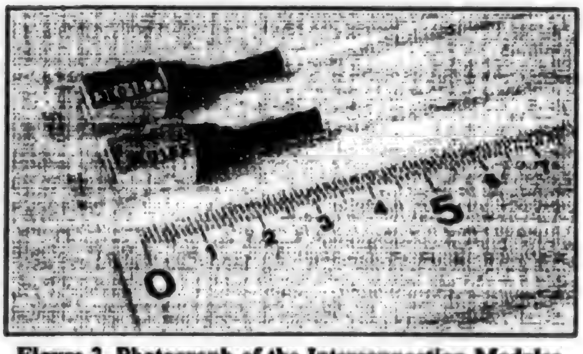


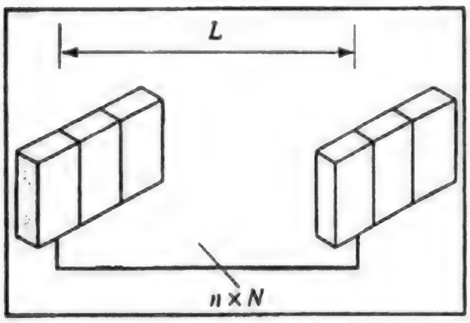
Figure 2. Photograph of the Interconnection Modules

Table 1 shows the target specifications of the modules. Transmission length over 100 m is expected by using the single-mode fiber array.

Table 1. Target Specifications of the Module

Term	Symbol	Value	Unit
Length	L	>100	m
Data rate	B	>200	Mbit/s/ch
Integration	n	8	ch
Skew	$\Delta\tau$	<2.0	ns
Bit error rate	P_c	$<1.0E^{-20}$	—
Power consumption	P	<200	mW/ch
Throughput density*	S	>100	Mbyte/cm^2

*(Data rate) x (Integration)/(Package area)



Skew suppression and error-free unformatted data transmission are important criteria, as well as small dimension and low power consumption. In order to meet these requirements we used an LD light source, SMF arrays and emitter-coupled logic (ECL) interface ICs.

An SMF array is necessary for meeting the requirement of minimizing skew. A skew of less than 2 ps/m is obtainable with an SMF array, while in an MMF array, it is 12 ps/m. The target skew of 2 ns for a 100-m transmission is difficult to satisfy with an MMF array because of the additional (for example, the module itself) skew.

Also, LD has advantages for high coupling efficiency to the SMF and high-speed modulation compared with LED. So, it will be suitable for SMF array transmission, low consumption operation and simple receiver circuit design. As for the skew suppression of the module itself, we introduce a very low threshold current LD in order to reduce the turn-on delay, which is the main cause of transmitter skew.

And, for error-free unformatted data transmission, we adopted a fully DC-coupled receiver circuit with a fixed decision level relative to the optical extinction level.

Devices

LD/PD Array

We recently developed a monolithically integrated 8-channel LD linear array, arranged at 250-μm intervals, that is the same as the fiber array. We used an InGaAs/InP buried hetero (BH) structure LD at a wavelength of 1.3 μm, because its high reliability has been confirmed in telecommunication applications. To obtain a low threshold current, each LD has an optimized multiple quantum well (MQW) active layer, a 200-μm short cavity and 70/90 percent asymmetric reflectivity coated facets. The threshold currents obtained were 3.0 +/- 0.2 mA and the deviation of the slope efficiency was 0.36 +/- 0.01 W/A at room temperature.[5]

We fabricated the monolithically integrated back incident InGaAs/InP pin PD arrays with a 50-μm diameter detection area. To reduce the parasitic capacitance, the PD array was soldered using the flip-chip bonding technique on a quartz submount. The total capacitance with submount and the responsivity obtained were 0.25 pF/ch and 0.96A/W/ch, respectively.[(6)]

Transmitter and Receiver ICs

Circuit diagrams of transmitter and receiver array ICs are shown in Fig. 3. Both ICs have identical 8-channel circuits and were fabricated using a high speed Si-bipolar process. All electrical interfaces are the conventional ECL level. Each transmitter circuit consists of an input buffer and a current switching LD driver. Owing to low threshold current LD arrays, the driver circuit was simplified by eliminating the automatic power control (APC) circuit.

Each receiver circuit consists of a transimpedance preamplifier, a post-amplifier, a comparator and an ECL buffer. They are fully DC coupled and have a fixed decision level.

Both ICs require a single -5.2V supply and have a power consumption of 1 W.

Module Fabrication

Each transmitter (or receiver) IC is bonded to a thin ceramic substrate, and the substrate and the LD (or PD) are soldered onto a metal package and connected using Au wires.

The optical coupling method between the fiber array and the LD (or PD) array is a micro lens array coupling technique. The single-mode fibers of the array are sandwiched and soldered between V-grooved silicon substrates. The fiber ends are slant polished in order to avoid the influence of the reflection.[(7)]

The precise optical alignment is carried out by using a process-control computer which controls the three axes micropositioners by scanning the maximum point of the first and eighth channel output power.

Finally, a metallic cap hermetically seals the module.

Characteristics

Module performances were tested using the fabricated transmitter and receiver optical interconnection modules with a 100 m SMF array in between.

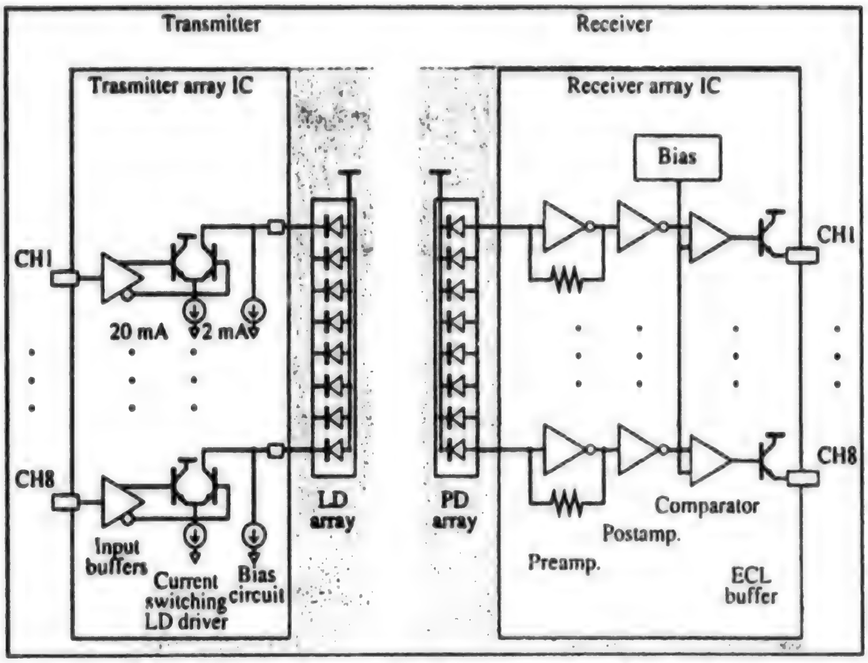


Figure 3. Circuit Diagrams of Transmitter and Receiver ICs

The typical fiber output power of the transmitter is shown in Fig. 4. The deviation of the output power between 8-channel which affects the receiver skew, which was measured to be less than 1 ns, is as small as 1 dB and the temperature tendency from 10 to 60°C is around 1.5 dB. Power dissipation was 1.9 W as a transmitter receiver pair.

The transfer curves of the receiver were measured and are shown in Fig. 5. High uniformity of the receiving level was obtained and the minimum optical receiving level for an ECL 10 K high level output was -14 dBm.

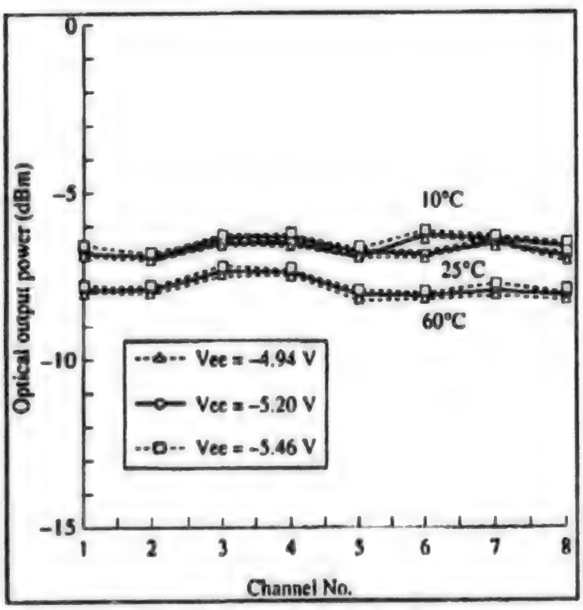


Figure 4. Fiber Output Power of the Transmitter

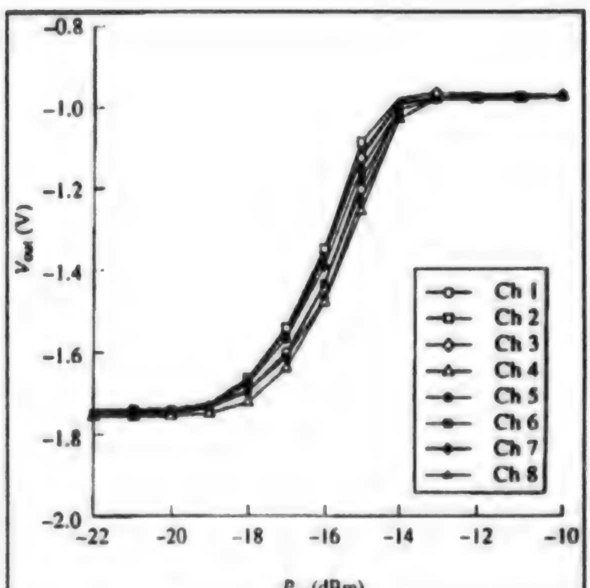


Figure 5. Transfer Curves of the Receiver

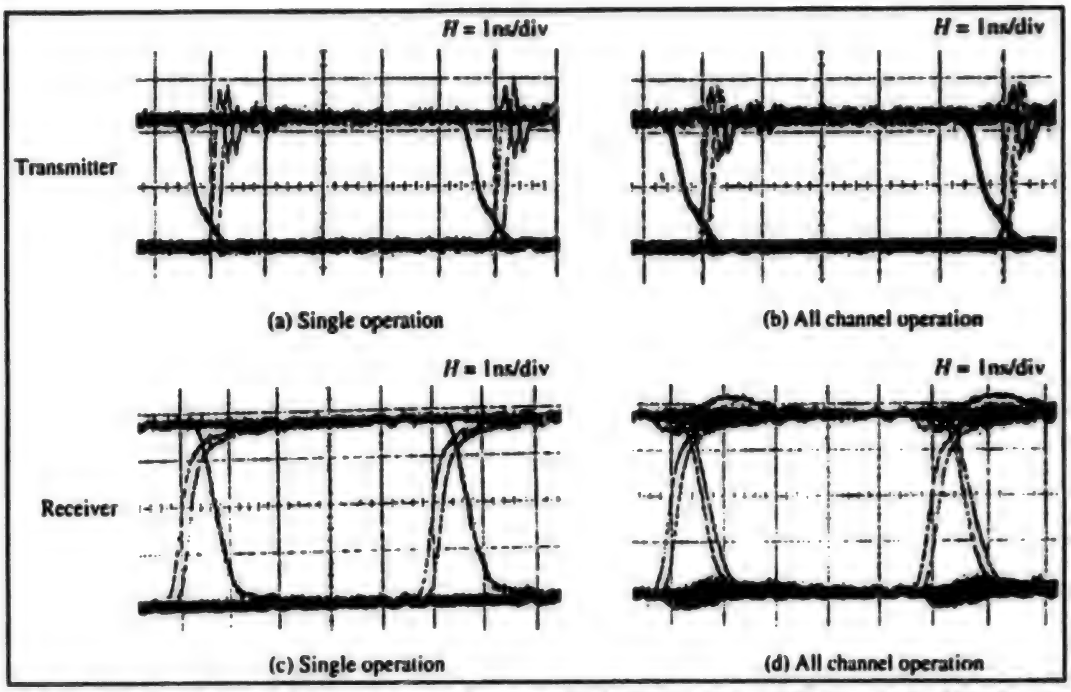


Figure 6. Output Waveforms of Transmitter and Receiver With/Without Cross Talk Caused by All Other Channels

The output waveform of the transmitter and receiver operating at 200 Mbit/s/ch are shown in Fig. 6. Fig. 6 (a) and (c) are at single channel operation and Fig. 6 (b) and (d) are all-channel operation. No appreciable waveform degradation due to the crosstalk from other channels was observed except for the switching noises which are acceptable for digital signals. Throughput of 200 Mbyte/s (200 Mbit/s/ch x 8 ch) was confirmed. Bit error rate better than 10^{-20} was estimated by a newly proposed method.[8]

These results combined confirm the achievement of target specification in Table 1.

Conclusion

We have developed fully integrated 200 Mbit/s 8-channel subsystem interconnection modules using a 1.3-μm wavelength and low threshold LD arrays, small capacitance PD arrays and array ICs in small packages coupled with a single-mode fiber array. The transmitter and receiver ICs are fully DC-coupled to enable unformatted data transmission.

The subsystem optical interconnections developed are expected to enhance the information throughput in the field of advanced large-capacity switching systems and high-speed computers.

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Electroabsorption Modulator Integrated Distributed Feedback Laser for 2.4-Gbit/s 160-km Transmission

43070117I Tokyo HITACHI REVIEW in English Apr 94 pp 83-86

[Article by Satoshi Aoki and Tsuyoshi Tanaka, Fiberoptics Division, Hitachi, Ltd.; and Masahiro Aoki, Central Research Laboratory, Hitachi, Ltd.]

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Abstract

High-speed transmission is a key technology in the effort to realize the B-ISDN (broadband integrated services digital network), which integrates various information services, such as telephony, video, and computer data. Economical implementation of the 2.4-Gbit/s transmission system demands the expansion of the repeater distance to double the conventional 80 km to 160 km. In order to meet this requirement, we have integrated an electroabsorption (EA) modulator with a distributed feedback laser diode (DFB-LD). They are monolithically integrated in an MQW (multiple-quantum well) structure by MOVPE (metal organic vapor phase epitaxy) and mounted in a compact package. This enables high speed and long distance transmission and features its compact size and low voltage operation over the so far realized external modulation by a combination of a separate modulator and a laser diode.

Introduction

Practical implementation of a high-speed fiber-optic transmission system as high as 2.4 Gbit/s is showing a rapid progress for the coming era of B-ISDN. For the economy of system implementation, transmission distance between regenerative repeaters is needed to expand to 160 km from 80 km which has been realized within only a few years. The use of conventional 1.3-μm zero-dispersion fiber already widely installed is requested with the sacrifice of the large dispersion at the operational wavelength of 1.5 μm selected for the minimum fiber loss.

Dispersion limits the maximum available transmission distance and a light source of narrow modulation spectrum is the prerequisite. Distributed feedback laser diode (DFB-LD) has been known to have a narrow spectrum under DC bias operation. However, it shows a spread of the spectrum under high speed operation, such as 2.4 Gbit/s, because of the chirp, or the wavelength shift by the modulation current. External modulation using an external modulator, based on semiconductor materials and $LiNbO_3$,[3] have been a solution with the expense of increasing the complexity of the system configuration.

In this paper, a more advanced solution is described where an EA modulator is monolithically integrated with a DFB-LD into a compact single device. The method of technological advancement is schematically described in Fig. 1. For the 2.488-Gbit/s transmission, the developed EA modulator integrated DFB-LD is confirmed to have expanded the regenerative repeater distance to 160 km from the previous record of 120 km by the conventional directly-modulated LD.

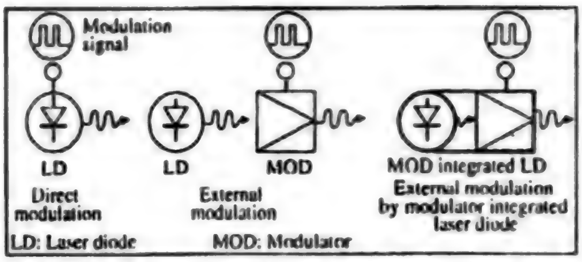


Figure 1. Advancement of Modulation Scheme. Direct modulation of a laser diode is replaced by an external modulation. Monolithic integration improves the compactness and coupling between the devices.

Device Structure and Design

A schematic structure of an EA-modulator integrated DFB-LD (DFB-LD/EA) device is shown in Fig. 2. The device, based on a separate confined-heterostructure (SCH) multiple quantum well (MQW) structure and a semi-insulating planar buried hetero (SI-PBH) structure, was grown by low-pressure metal organic vapor phase epitaxy (MOVPE). The MQW structure has been known to give satisfactory results in long wavelength lasers. In addition, quite recently, it has also proved to be a good material for EA modulators, from the viewpoint of modulation efficiency, high-speed performance and chirping characteristics.[1] An optical waveguide was inserted between the laser and modulator regions. The bandgap energies of each region were controlled by selective area MOVPE.[4]

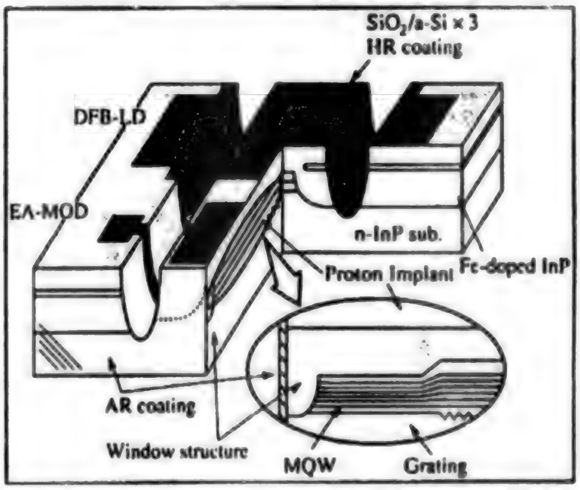


Figure 2. Structure of an EA-Modulator Integrated DFB-Laser

The wafer was processed into SI-PBH structure doped with Fe. A proton (H^+) implant region was then made between the modulator and the laser section to reproducibly obtain sufficient electrical isolation. To reduce wavelength chirp caused by the optical feedback from the modulator front facet, we employed a window structure combined with an anti-reflection coating with reflectivity less than 0.2 percent. The laser rear facet was coated with a highly-reflective film (90 percent) to enlarge the output efficiency of the lasing light.

Fundamental properties

Fig. 3 shows typical I-L curves (light output power vs. current) of a 650-µm long device (laser 400 µm, modulator 200 µm, separation 50 µm). The threshold current and slope efficiency without modulation bias were 18.0 mA and 0.10 W/A. An output power greater than 10 mW was easily obtained. These lasing properties, comparable even with those of discrete lasers, reflect the high quality of the selectively grown crystals, efficient waveguide coupling between the devices, and sufficient current blocking by the thick Fe-doped layer. Typical on/off ratios were 22 dB.

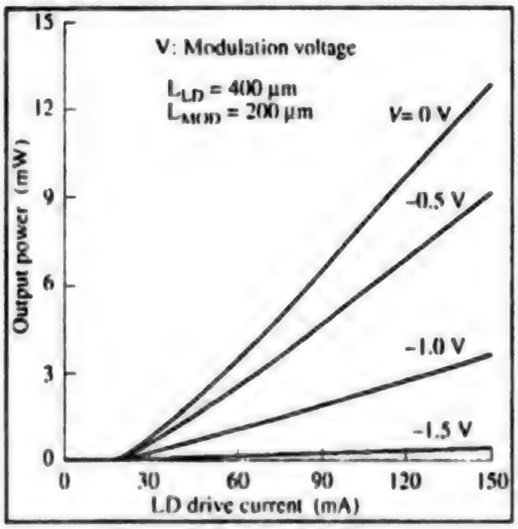


Figure 3. Typical I-L Curves

The attenuation is less sensitive to the laser driving currents, i.e., dependence on optical intensity was sufficiently small. This will be important for the linearity in high-power operation of such photonic devices using EA effects. It is important to note that these excellent modulation properties enable bias-free and low voltage operations of the modulator. This means that the device requires only two electrical inputs, i.e., the laser driving current and the modulation signal, which is the same as for the simple direct modulation of laser diodes. Furthermore, low voltage operation less than 2V will simplify the driver electronics.

Module Design

The main characteristics and module configuration are shown in Table 1 and Fig. 4, respectively. A monolithic EA modulator integrated DFB-LD chip was mounted on a carrier with a 50-Ω microstrip line and a 50-Ω terminating thin film resistor. This module matched the 50-Ω input impedance and contained a 30-dB isolator in an optical coupling system, a monitor photodiode and temperature controlling devices such as a thermoelectric cooler and a thermistor. All these elements were assembled by fluxless soldering and YAG (yttrium aluminum garnet) laser welding in the 14-pin butterfly 2.6-cm^3 hermetically sealed package.

Table 1. Characteristics of the DFB-LD Integrated EA Modulator Module. The extinction ratio accomplished more than 20 dB with less than 2 V_{p-p} driving voltage. Chip temperature = 25°C

Item	Symbol	Characteristics	Unit
Output power	P_f	≥1.5*	mW
Extinction ratio	ER	≥20	dB
Driving voltage	V_{mp-p}	≤2	V
Peak wavelength	λ_p	1550+/-20	nm
Bandwidth (-3 dB)	BW	≥4	GHz
Rise/fall time	t_r/t_f	Typ. 90/100**	ps
TE cooler capacity	ΔT	≥40	K
Tracking error	ΔP_f	≤0.5	dB
Optical isolation	L_B	≥30	dB
Input impedance	Z_{in}	50	Ω

Conditions: *CW, $I_F = I_{th} + 50$ mA

**2.488 Gbit/s, NRZ, PRBS: 2^{23}-1, Mark ratio ½ V_{mp-p} = 1.8 V, $I_F = I_{th} + 50$ mA

DFB-LD/EA: Distributed feedback-laser diode integrated electroabsorption modulator; I_F: Laser forward current; NRZ: Nonreturn to zero; TE: Thermoelectric; PRBS: Pseudorandom bit sequence; CW: Continuous wave

A 3-dB bandwidth and return loss of this package were found to be more than 10 GHz and less than 15 dB from 0 to 10 GHz, respectively. The confocal double lenses coupling system adopted for highly efficient coupling of the DFB-LD/EA chip to a single mode fiber has resulted in a typical coupling loss of 3 dB which includes the loss of an optical isolator. Therefore, an average output power of -1 dBm was obtained under the operating condition of DFB-LD at I_{th} (threshold current) +50 mA.

When the DFB-LD is operated at I_{th} +50 mA in the ambient temperature of 65°C, it can be cooled down to 25°C by a thermoelectric cooler with 1.2 A. The tracking error of the fiber output power is only 0.2 +/- 0.1 dB against an ambient temperature within -20°C to 65°C, when the DFB-LD/EA chip output power is kept constant by an APC (automatic power control) and the chip temperature is kept at 25°C by an ATC (automatic temperature control).

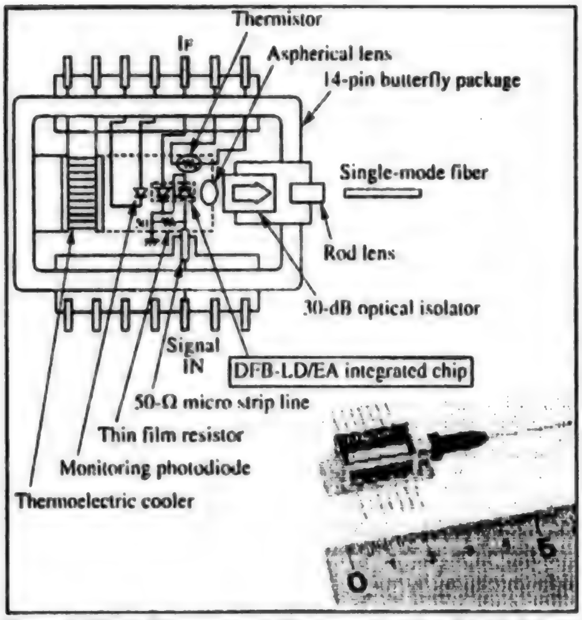


Figure 4. Block Diagram and Photograph of the EA Modulator Integrated DFB-LD Module. A DFB-LD/EA chip, a monitoring photodiode, a thermistor and a thermoelectric cooler are contained in a 14-pin butterfly 2.6-cm³ hermetically sealed package with an optical isolator of 30-dB isolation.

Performance

The small signal frequency response shown in Fig. 5 was measured with a PIN photodiode having a 3-dB bandwidth of 14 GHz. The bandwidth of the DFB-LD/EA module is obtained more than 6 GHz.

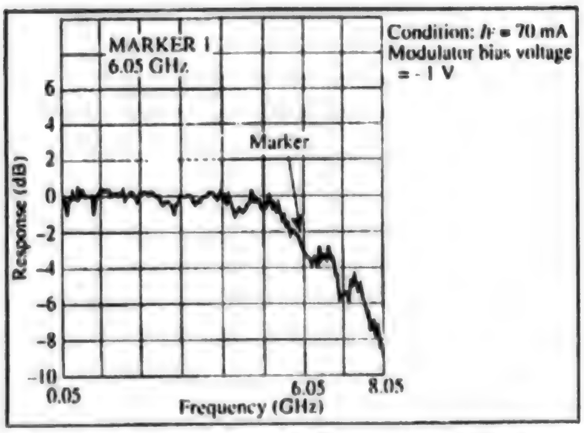


Figure 5. The Small Signal Frequency Response of the EA Modulator Integrated DFB-LD Module. The 3-dB bandwidth obtained 6.05 GHz.

An eye pattern and modulated spectrum under the condition of 2.4 Gbit/s, NRZ (nonreturn to zero), pseudorandom sequence 2^{23}-1 and bit error rate up to 160 km is shown in Fig. 6. The bit error rate characteristic of a conventional LD module under direct intensity modulation is compared in Fig. 7. Because of the loss of the 160-km fiber being 36 dB, the measurement of the bit error rate characteristics used in the EDFA (erbium-doped fiber amplifier) is as shown in Fig. 8.

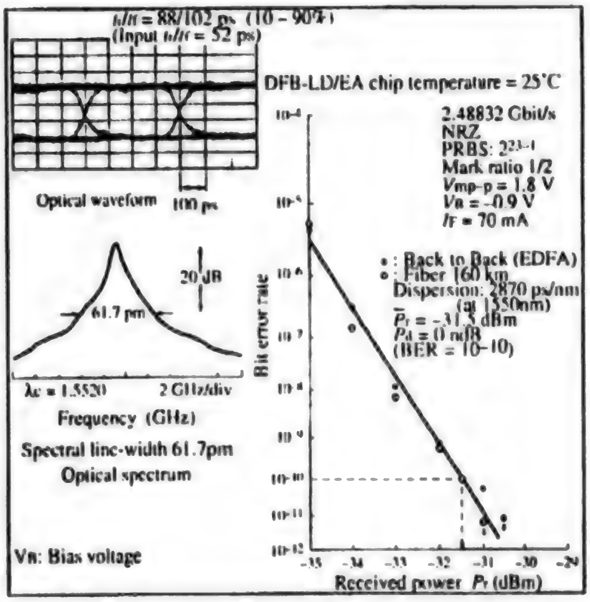


Figure 6. The Optical Waveform, the Optical Spectrum and the Bit Error Rate Characteristics of the EA Modulator Integrated DFB-LD. The received sensitivity obtained -31.5 dBm at a bit error rate of 10^{-10} with dispersion loss is 0 dB from back to back to 160 km transmission with 2870 ps/nm dispersion.

Transmission up to 120 km is possible in the case of the conventional LD module using direct intensity modulation. However, the error floor caused by waveform distortion due to fiber dispersion (2900 ps/nm) and LD's chirp occurred at 160 km as shown in Fig. 7. It is possible to transmit even if the transmission distance is 160 km in the case of the DFB-LD/EA module as shown in Fig. 6. Modulation voltage of only 1.8V is necessary to operate the EA modulator. The modulated spectral line width of the DFB-LD/EA module is 62 pm as one-sixth of the conventional LD, under direct modulation. The waveform distortion due to fiber dispersion and chirp is much lower than the conventional LD module. Accordingly, the DFB-LD/EA module confirmed the possibility of long haul transmission of at least 160 km, or twice that of the conventional standard transmission distance.

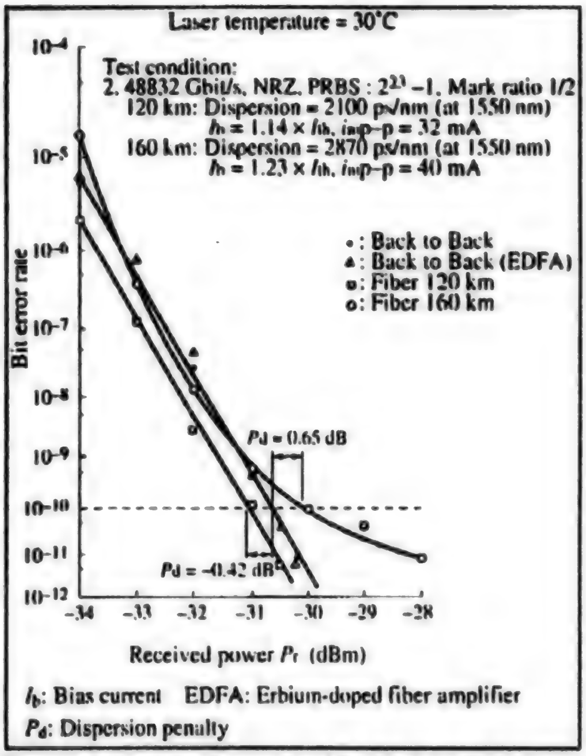
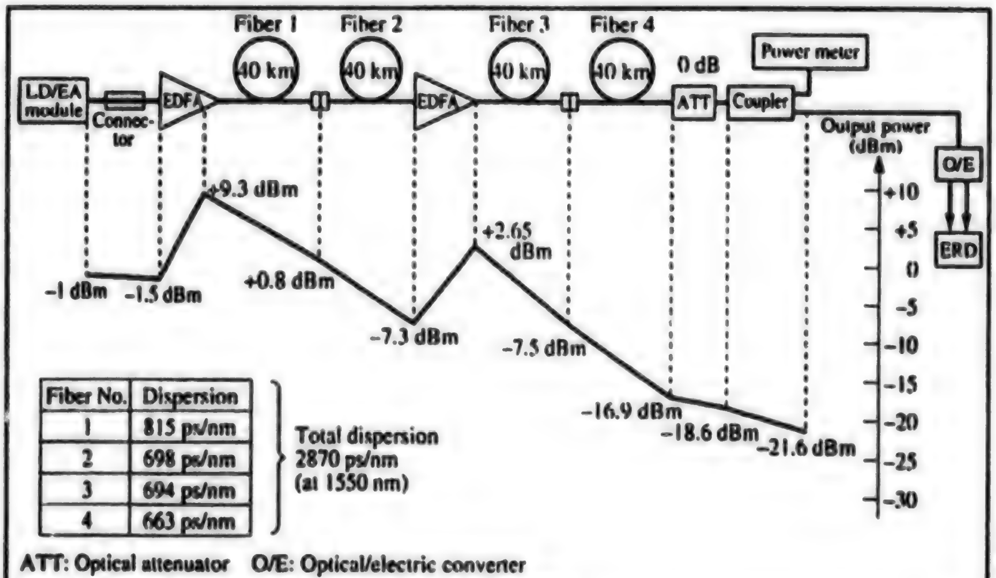


Figure 7. The Bit Error Rate Characteristics of the Conventional LD Module With Direct Intensity Modulation. The error floor caused by waveform distortion due to fiber dispersion and LD's chirp occurred at 160 km transmission.



Fiber No.	Dispersion
1	815 ps/nm
2	698 ps/nm
3	694 ps/nm
4	663 ps/nm

Figure 8. Bit Error Rate Characteristics Testing Configuration and Level Diagram of the EA Modulator Integrated DFB-LD Module. The fiber output power of the transmitting module was amplified to +9.3 dBm by the first EDFA, and the transmission signal passed through 80-km fiber, was again amplified by the second EDFA with about 10-dB gain. The loss of 160 km fiber with 2870-ps/nm dispersion is about 36 dB.

Conclusion

The EA modulator is monolithically integrated with DFB-LD. It can operate as a light source for long haul transmission because of its very narrow spectral linewidth and its very low chirp. It is mounted in a compact 14-pin butterfly package with 50-Ω input impedance matched together with a monitor photodiode, temperature controlling devices (a thermoelectric cooler and a thermistor) and a 30-dB optical isolator. This EA modulator integrated DFB-LD module was confirmed to achieve stable operation at 2.4-Gbit/s 160-km transmission with less than 2.0 V_{p-p} modulator voltage. This module will contribute to the economical implementation of high-speed fiber-optic system for the B-ISDN.

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Fiber-Optic Semiconductor Devices for Fiber-in-the-Subscriber-Loop System

43070117J Tokyo HITACHI REVIEW in English Apr 94 pp 87-90

[Article by Shoichi Takahashi, Shigehisa Sano, and Masakatsu Yamamoto, Semiconductor and Integrated Circuits Division, Hitachi, Ltd.]

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Abstract

Expansion of subscriber fiber-optic systems depends on services to be provided and on reduction in cost. In order to expand these systems, we have developed a bidirectional module, which transmits and receives signals through a single optical fiber, to reduce the cost of the fiber-optic system. Wavelength division multiplexing (WDM) is adopted, in which two different wavelengths are used for transmission and reception. A technique to suppress optical crosstalk (leakage of signals from the transmitter to the receiver) and the development of a wide operating temperature range laser diode are key issues for the development of the module. We hope that installation of optical fiber into subscriber systems will be promoted by the use of this module.

Introduction

Telecommunication services are moving from conventional analog based voice and data to the narrowband integrated digital services network (N-ISDN). The services will evolve to the broadband (B-)ISDN during the last decade of this century. Video service will be provided and optical fiber will transport information, video, voice, and data to each home by a system called fiber-to-the-home (FTTH). We have been investigating these systems since the early stages. The reduction of the cost of the systems is important in instituting FTTH, so bidirectional optical network systems to realize transmission and reception on a single fiber are expected. This paper describes a bidirectional module that has been developed for application to such subscriber systems.

Subscriber Systems and Bidirectional Transmission

Configuration of Fiber-Optic Systems

Fig. 1 shows an outline of the subscriber fiber-optic systems. The ultimate form is FTTH, which brings optical fiber to each house, though the transition from metallic cable to optical fiber varies according to national and social demands at the time of installation. But, it is difficult to construct FTTH immediately, from the economical point of view. Construction of FTTC (fiber-to-the-curb), which installs optical fiber only to points near the house, will be promoted for the time being. In the future, the replacement by FTTH will be accelerated if various attractive services and multimedia terminals are supplied at low cost.

Bidirectional Transmission Issues

There are two typical methods used for allowing subscribers to transmit and receive information[1],[2]; one is WDM (wavelength division multiplex), and the other is DDM (direct division multiplex). In a WDM system, two different wavelengths are used for the transmitter and receiver, respectively. On the other hand, a single wavelength is used in the DDM system. The WDM system is more effective because of less optical crosstalk between the transmitted and received signals. Fig. 2 shows a summary of the WDM system.

Reducing cost is also one of the most important issues for extension of subscriber systems. For this reason, there is a need for a bidirectional module that transmits and receives signals over a single optical fiber, can differentiate wavelengths and comes in a small package.

Moreover, the module must have a wide operating temperature range. Subscriber systems must simplify equipment, such as removing the thermal controllers, to reduce cost. The required operating temperature is -40 to +85°C.

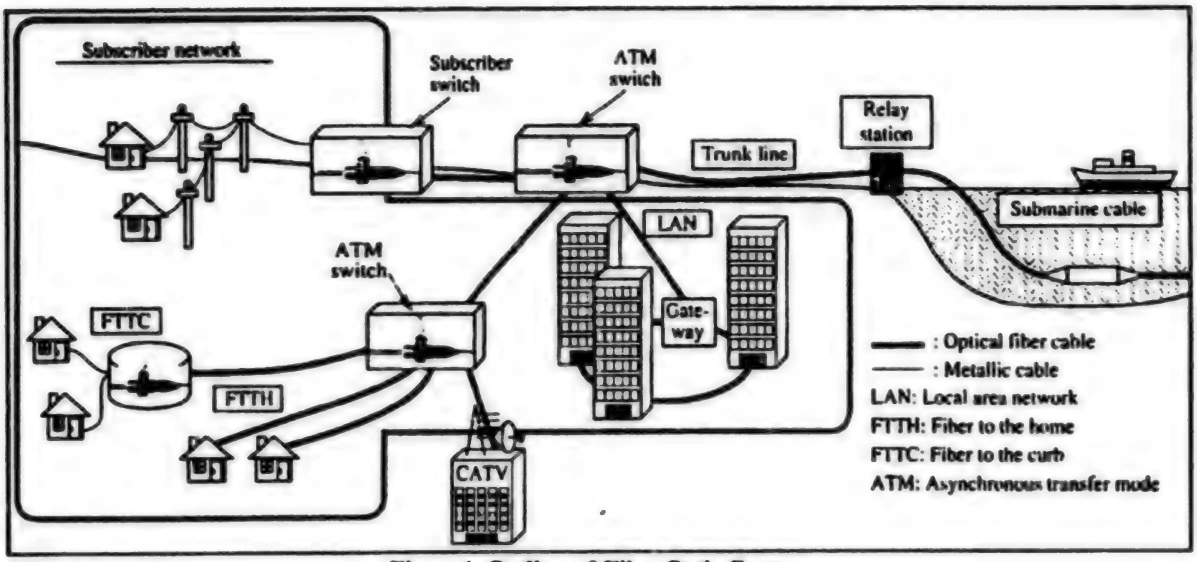

Figure 1. Outline of Fiber-Optic Systems

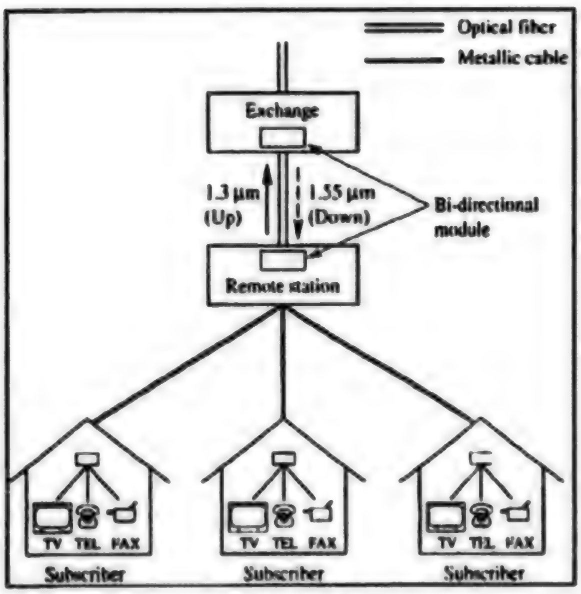

Figure 2. Summary of Bidirectional Transmission (FTTC/WDM)

Wide Operating Temperature Range Laser Diode

A 1.3-µm multiple quantum well (MQW) Fabry-Perot (FP) laser diode, satisfying the wide operating temperature range requirement (-40 to +85°C), has been developed using a metal organic chemical vapor deposition (MOCVD) method. Fig. 3 shows the schematic structure of the device. By using the MOCVD method for entire crystal growth instead of the formerly used liquid phase epitaxy (LPE), we found it to have the excellent feature of controllability for mass production. We introduced the MQW structure into the active layer in the laser. The MQW structure, the active region, is made by growing several thin film active layers a few nm thick, called the well layer and barrier layer, periodically. Making the active layer thinner, on atomic order, produces a quantum size effect for the electrons, and increases the radiation efficiency of the carriers. It also suppresses self-heating of the laser, so the laser operates stably at high temperatures up to +85°C. We called this laser a constricted blocking layer on p-substrate buried heterostructure laser (CBPBH laser), because of the form of the n-InP blocking layer close to the active layer. It is important to reduce leakage current between the active layer and the n-InP blocking layer. This laser reduces leakage current by forming a p-InP buffer layer and n-InP blocking layer that are well controlled with the MOCVD technique, in contrast to conventional LPE methods.

Bidirectional Module With Low Cost and Low Optical Crosstalk

T[illegible]ss optical crosstalk, an optimized structure for optical filter positioning has to be found. We have developed a bidirectional module (HLM 1332) employing this, as shown in Fig. 4.

This module transmits signals with 1.3-µm wavelength signals and receives with 1.55-µm wavelength signals. A module which transmits 1.55-µm wavelength signals and receives 1.3 µm wavelength signals is a counterpart of the HLM 1332.

(1) Construction of the optical system

Fig. 5 shows the configuration of the optical components for this module. This system makes it possible to both

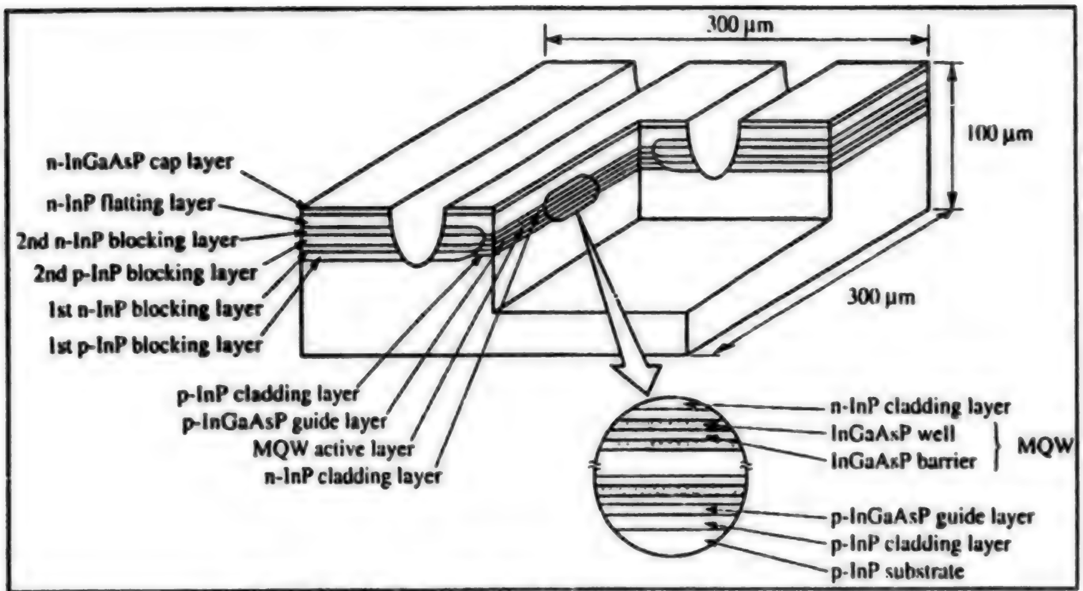

Figure 3. 1.3-μm WTR-FP-LD (HL 1326) Schematic View

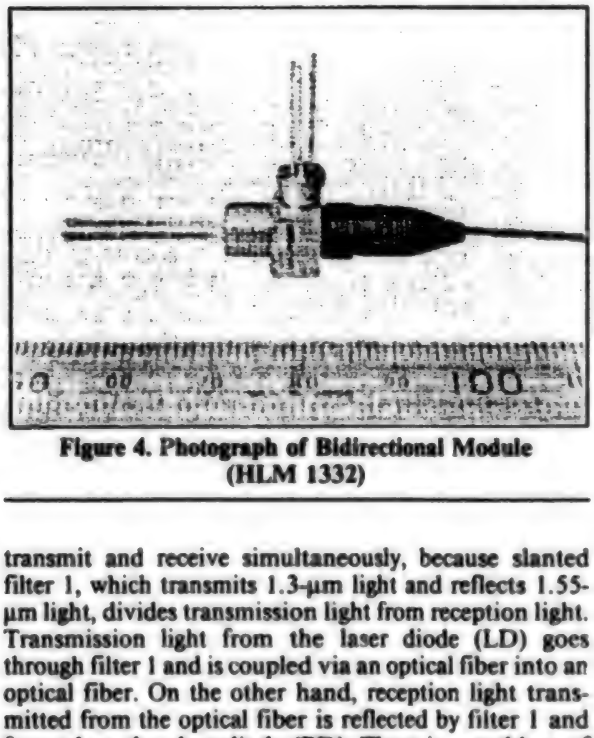

Figure 4. Photograph of Bidirectional Module (HLM 1332)

transmit and receive simultaneously, because slanted filter 1, which transmits 1.3-μm light and reflects 1.55-μm light, divides transmission light from reception light. Transmission light from the laser diode (LD) goes through filter 1 and is coupled via an optical fiber into an optical fiber. On the other hand, reception light transmitted from the optical fiber is reflected by filter 1 and focused on the photodiode (PD). There is a problem of leakage light in this system. This leakage is caused since part of the transmitted light is reflected by filter 1 and by the end of the optical fiber and combines with the receiver light. The leakage light must be small to have reasonable optical crosstalk value for proper bidirectional transmission performance. (The ratio of PD sensitivity from the leakage light to the PD sensitivity from the reception light is defined as the optical crosstalk.) By optimizing the assembly of filter 1, the positioning, and the adoption of a low reflection light structure and filter 2, a low crosstalk of -45 dB or less can be obtained. Also, by adopting a single lens for coupling in each optical system and conventional filters, this module can be supplied at a low price.

(2) Main features

Table 1 shows the optical and electrical characteristics of the HLM 1332. Fig. 6 shows examples of module characteristics. By adopting the wide operating temperature range laser diode HL 1326 with an MQW structure and yttrium aluminum garnet (YAG) laser welding, this module can operate over a wide temperature range, -40 to +85°C. Also, adoption of structure based optical packaging techniques using a non-spherical lens makes possible a small package (about 1 cc), a high optical power, 1.6 mW or more, and a high receiver sensitivity, 0.6 A/W or more. And, this module has a low relative intensity noise (RIN), as shown in Fig. 6.

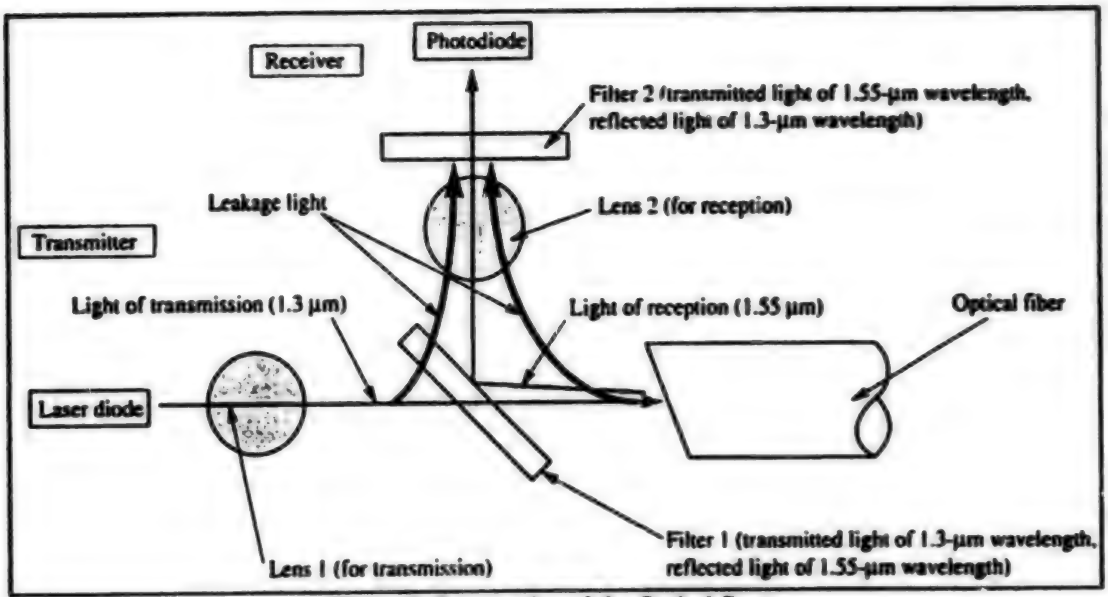

Figure 5. Construction of the Optical System

Table 1. HLM 1332 Optical and Electrical Characteristics (T_c = 25°C)

Item	Symbol	Test Conditions	Min	Typ	Max	Unit
Operating equipment	T_{opr}	—	-40		85	°C
Storage temperature	T_{stg}	—	-40		85	°C
LD optical output power	P_f	Kink free	1.6	—	—	mW
	P_f	$I_F = I_{th} + 20$ mA	0.8	—	—	mW
LD threshold current	I_{th}	—	—	10	20	mA
Lasing wavelength	λ_p	P_f = 1.6 mW	1280	1310	1340	nm
Spectral width	$\Delta\lambda$	P_f = 1.6 mW	—	3	—	nm
Monitor PD current	I_s	P_f = 1.6 mW, V_R(MPD) = 5 V	100	—	—	µA
Receiver PD sensitivity	S	λ pin = 1550 nm, V_R(RPD) = 5 V	0.6	—	—	A/W
Receiver PD dark current	I_d(RPD)	V_R(RPD) = 5 V	—	1	5	nA
Receiver PD capacitance	C_t	V_R(RPD) = 5 V, f = 1 MHz	—	1	1.5	pF
Optical crosstalk	LI	P_{in} = 1 µW (1550 nm), P_f = 1 mW (1310 nm), V_R(RPD) = 5 V	—	—	-45	dB

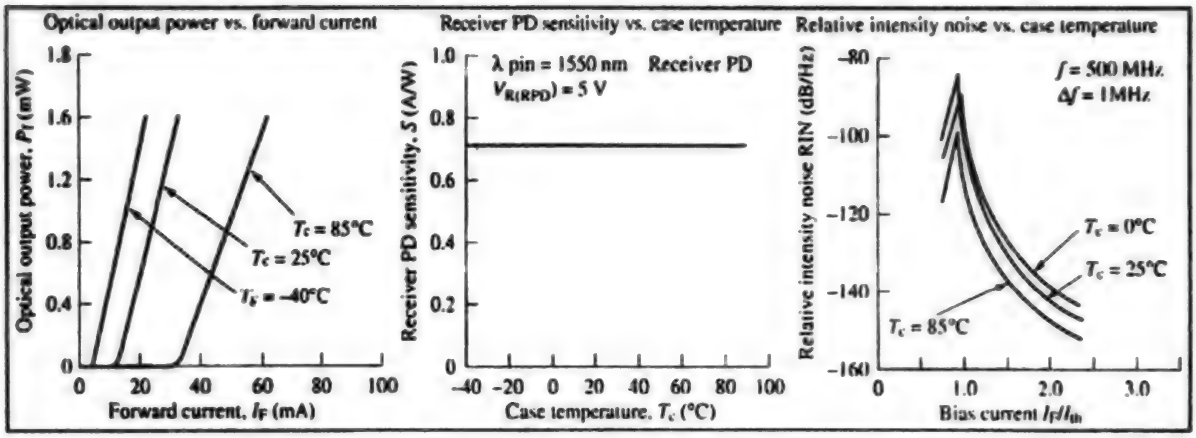

Figure 6. Examples of Optical and Electrical Characteristics

(3) Applications

This module is suitable for FTTC WDM systems which transmit 1.3-μm optical signals and receive 1.55-μm optical signals.

Conclusion

We have developed a bidirectional module for WDM subscriber fiber-optic systems. The laser diode in this module can operate over a wide temperature range, -40 to +85°C, by adopting the MQW structure, which is produced using the MOCVD technique. By optimizing the assembly of the filters and the positioning, a low crosstalk of -45 dB or less can be obtained. We believe this module can contribute to effectively reducing the cost of fiber-optic systems.

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GaAs IC Set for 2.4-Gbit/s Optical Transmission Systems

43070117K Tokyo HITACHI REVIEW in English Apr 94 pp 91-94

[Article by Yasushi Hatta and Chiyoshi Kamada, Device Development Center, Hitachi, Ltd.; and Makoto Haneda, Semiconductor and Integrated Circuits Division, Hitachi, Ltd.]

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Abstract

The GaAs IC set has been developed for use in 2.4-Gbit/s optical transmitter and receiver modules. The IC set consists of seven types of ICs. They are: the laser drivers for transmitter and preamplifier, the AGC (automatic gain controllable) amplifier, the main amplifier, the decision circuit, the rectifier, and the limiting amplifier for the receiver module. The ICs are designed to have good 50-impedance matching interface and a flat response gain-frequency characteristic. 2.4-Gbit/s optical transmission experiments using the above IC set showed an excellent receiver sensitivity of -32 dBm after 40-km optical fiber transmission, meeting the international standard of -26 dBm with a sufficient margin.

Introduction

Recently, 2.4-Gbit/s optical transmission systems have been progressively introduced for practical use. Such systems require high speed transmitter and receiver circuits, and therefore the development of monolithic ICs is indispensable to achieve low power dissipation, compactness and high reliability. For ICs, high gain, wide band and low noise characteristics, as well as low power dissipation are required. To realize these requirements, we have developed an IC set specifically for use in 2.4-Gbit/s optical transmission systems using a 0.8-μm gate GaAs MESFET (metal semiconductor field effect transistor) device which has a high cut off frequency (f_t) of 24 GHz and a high maximum operating frequency (f_{max}) of 34 GHz.[1,2] A typical block diagram of a 2.4-Gbit/s optical transmitter and receiver using the IC set is shown in Fig. 1. In this paper, the design and test results of the ICs are described.

IC Design and Performance

Seven types of GaAs ICs have been developed using a 0.8-μm gate GaAs MESFET. Features of the ICs are summarized in Table 1. Most circuits consist of a multistage source coupled FET logic (SCFL) with differential drive in order to achieve the high gain and wide allowable threshold voltage (V_{th}) range of the FETs. The ICs can be operated with a single -5.2V power supply except for the preamplifier. Power dissipation of the ICs is less than 1 W and each IC can be operated in natural air convection. As for packaging,

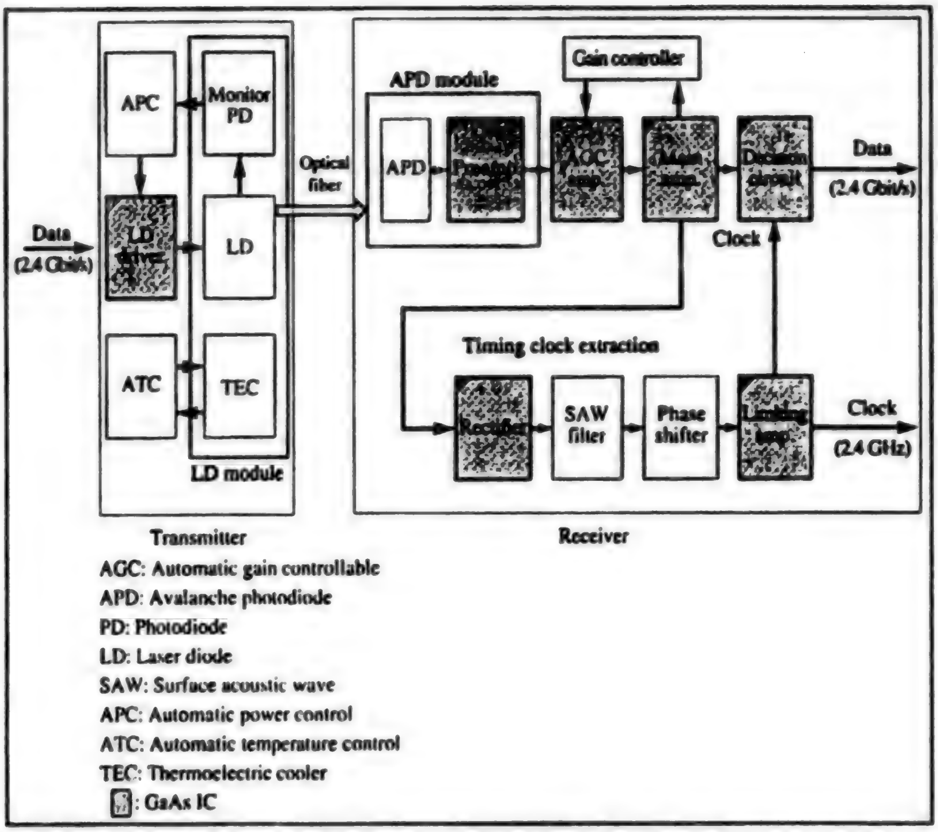


Figure 1. Block Diagram of 2.4-Gbit/s Optical Transmitter and Receiver. The laser driver in the transmitter is housed in a 14-pin package. The preamplifier hip is mounted in an APD module. The other ICs are housed in a 20-pin package with an internal input termination resistor and noise decoupling capacitors.

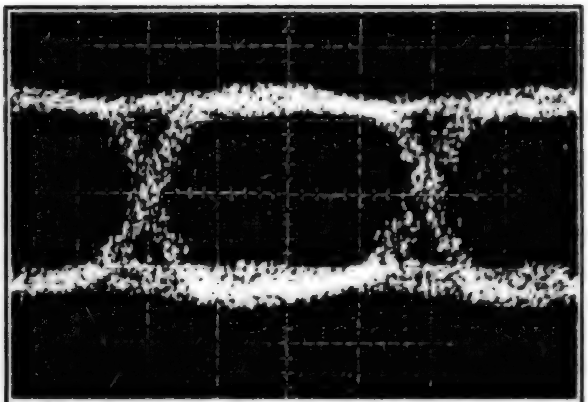
the laser driver is housed in a 14-pin package, while the other ICs are housed in 20-pin packages. The packages are shown in Fig. 2 [not reproduced]. The preamplifier IC is not packaged in order to minimize the parasitic capacitance by directly mounting in an APD (avalanche photodiode) module.

Table 1. Main Characteristics of the GaAs ICs. Power dissipation is less than 1 W and each IC can be operated in natural air convection.

Function	Part No.	Main characteristics	Supply voltage (V)	Power dissipation (W)	Package
Laser driver	HA 29001	Maximum signal current: 60 mA Output t_r/t_f: 120 ps	-5.2	0.4	14 pin
Preamplifier	HC29202	Transimpedance: 800 Ω Equivalent input noise current: 7 pA/Hz squared	5.0 5.2	0.3	—
AGC amplifier	HA29203	Maximum gain: 23 dB Dynamic range: 40 dB	-5.2	0.8	20 pin
Main amplifier	HA29204	Gain: 20 dB Number of output pins: 4	-5.2	0.8	20 pin
Decision circuit	HA29201	Decision sensitivity: 50 mV Phase margin: 250°	-5.2	0.8	20 pin
Rectifier	HA29205	Transform efficiency: 40%	-5.2	0.6	20 pin
Limiting amplifier	HA29206	Minimum input amplitude: 30 mV_{p-p} Output signal amplitude: 600 mV_{p-p}	-5.2	0.8	20 pin

The laser driver has to drive a high current of 60 mA with rise and fall time of less than 120 ps. In order to achieve a clear output waveform, ringings on output signals which are caused by parasitic inductances should be suppressed. The 14-pin package is designed to have a short bonding wire of less than 1mm and to have multiple bonding wires on power supply connections. Fig. 3 shows the output eye diagrams of the laser driver with a signal current of 40 mA. Rise and fall time in the 10-90 percent range is 100 ps, and ringings are well suppressed.

For the implementation of high speed and high sensitivity receiver ICs, cascadability and flatness of frequency response should be considered. Fig. 4 shows an input signal termination circuit diagram.[3] High frequency signals (>30 MHz) are terminated with a 100 pF capacitor in the 20-pin package, while low frequency signals (<30 MHz) are terminated by a large capacitor outside of the package. Resistors for 50-Ω termination are divided into three resistors (47 Ω and two 6 Ω) to avoid resonance caused by the termination capacitors and parasitic inductances of package pins and bonding wires. For the output circuit, a resistor is inserted between the output source follower and the output pin to match 50 Ω impedance. On the IC layout design, wire cross on signal lines is avoided as far as possible and noise decoupling capacitors are implemented on the IC chip with a MIM (metal-insulator-metal) structure as well as capacitor chips in the package.



Vertical scale: 500 mv/div.
Horizontal scale: 100 ps/div. Electrical output through resistive load of 25 Ω with driving current of 40 ms.

Figure 3. Output Eye Diagrams of the Laser Driver. Output rise and fall time is 100 ps (10-90 percent) and ringings are well suppressed.

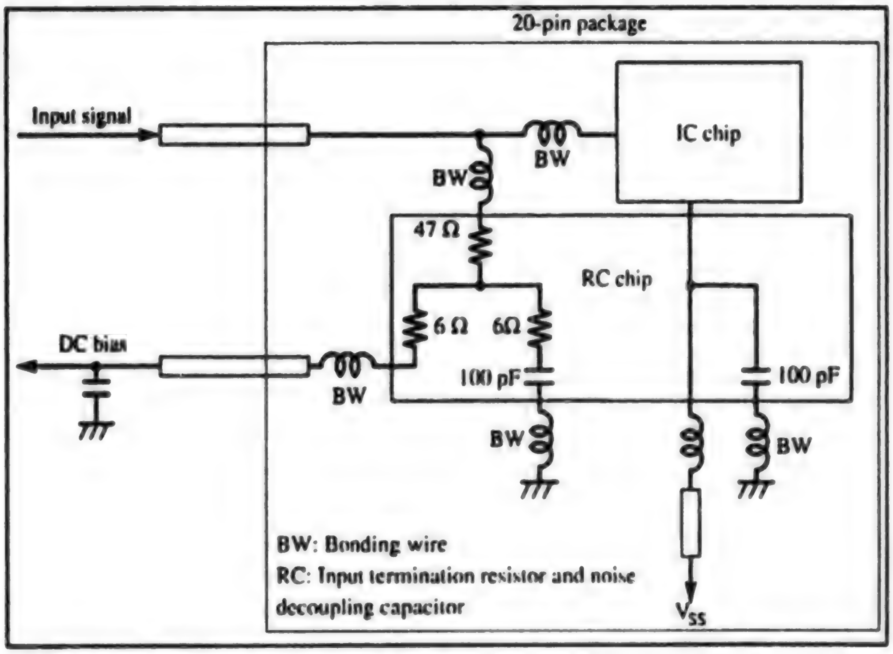


Figure 4. Circuit Diagram of the Input Termination Circuit. The 20-pin package has an internal RC chip in order to achieve a good 50-Ω impedance matching characteristic in the wide frequency range.

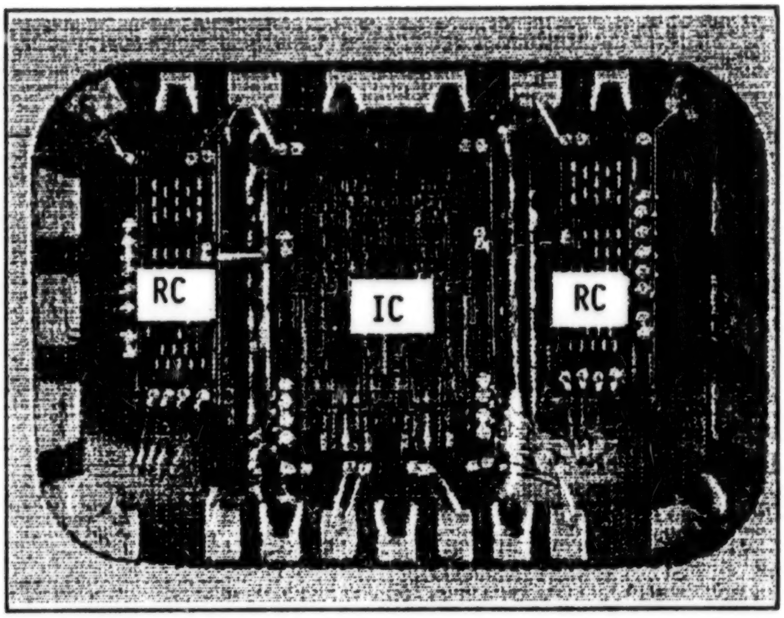


Figure 5. Inner View of the 20-Pin Package. The IC chip, RC chips, and the package are connected to each other with bonding wires.

Fig. 5 shows an internal view of the 20-pin package.[4] A GaAs IC chip, termination resistor and a noise decoupling capacitor chip (RC chip) are tightly housed in the package.

Fig. 6 shows the gain-frequency characteristics of the main amplifier and Fig. 7 shows the VSWR (voltage standing wave ratio) characteristics of the IC. Gain fluctuation is less than 1 dB with a high gain of 21 dB up to 2.4 GHz and VSWR is as low as 1.5 in the frequency range of near DC to 2.4 GHz. The results show flat frequency response as well as good impedance matching both on input and output ports.

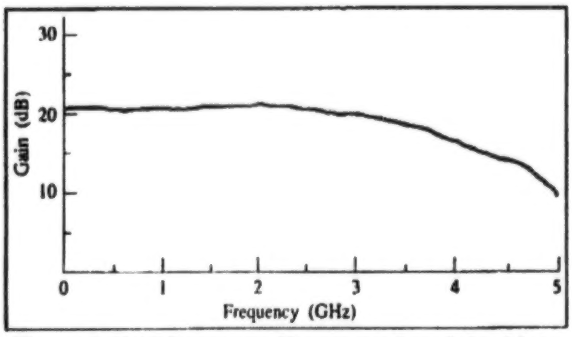


Figure 6. Gain-Frequency Characteristics of the Main Amplifier. Gain fluctuation is less than 1 dB with a high gain of 21 dB up to 2.4 GHz.

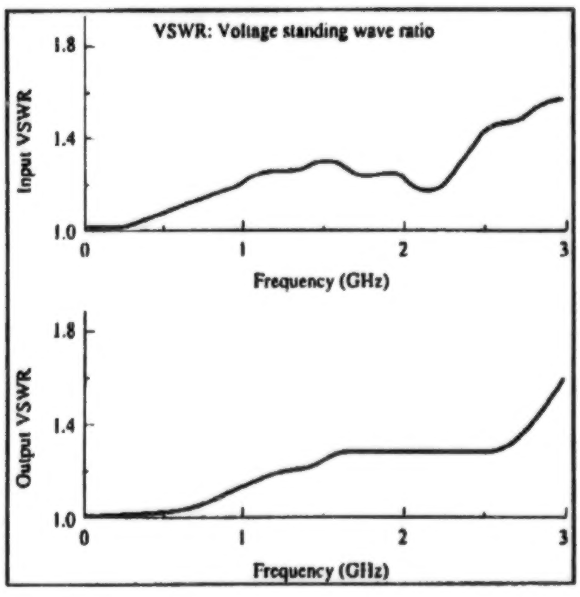


Figure 7. Input and Output VSWR Characteristics of the Main Amplifier. VSWR is as low as 1.5 with a frequency range of from near DC to 2.4 GHz both on input and output ports.

Optical Module Experiment

In order to examine the usefulness of the IC set, an optical transmission experiment was carried out. A 1.3-μm wavelength DFB (distributed feed back) laser diode was used as an optical source and an APD was adopted as an optical detector. An error rate characteristic of 2.4 Gbit/s is shown in Fig. 8. Receiver sensitivity of -32 dBm at a bit error rate of 10^{-10} was obtained after 40-km optical fiber transmission. The results meet the ITU-T (formerly CCITT), standard of -26 dBm with a sufficient margin.

Conclusion

Using the 0.8-μm gate GaAs MESFET, seven types of GaAs ICs were developed specifically for use in 2.4-Gbit/s optical transmission systems. Development of a new package with an internal input signal termination circuit enables the IC a flat response gain-frequency characteristic as well as good impedance matching interface. Optical transmission experiments showed the IC set is feasible for 2.4-Gbit/s optical transmission systems.

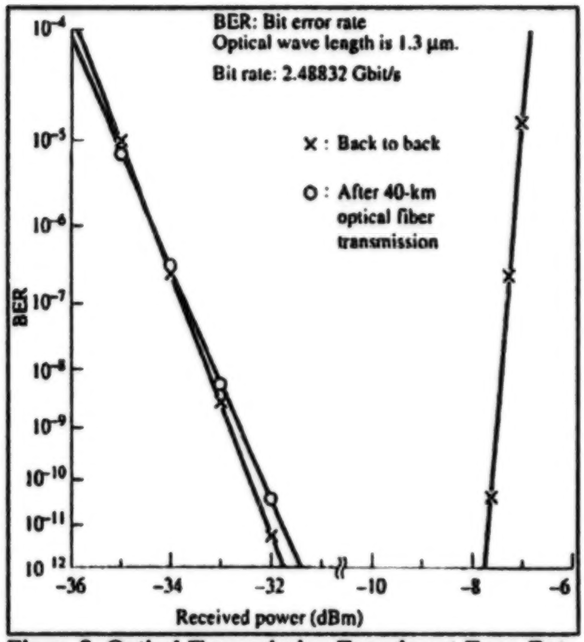


Figure 8. Optical Transmission Experiment Error Rate Characteristics. The experiment was carried out using the IC set. The receiver sensitivity is as high as -32 dBm at BER of 10^{-10}.

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